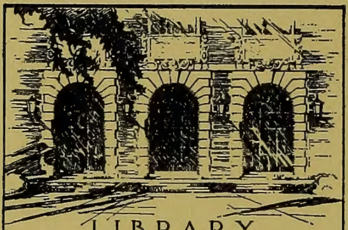

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TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM
PART II - SWITCHING CIRCUIT THEORY
PART III - MATHEMATICAL METHODS
PART IV - ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

January, 1958

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PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part through Contract No. AT(11-1)-415 of the Atomic Energy Commission. The contract is supported jointly by the Atomic Energy Commission and the Office of Naval Research. In addition, this work is supported through Contracts N6ori-07130 and Nonr-1834(15), both from the Office of Naval Research.

The University of Toronto is participating in this work through staff members of its Computation Centre.

1. Transistor Circuits

The possibility of designing high-powered drivers for asynchronous circuits, using GF 45011 transistors with 200 mw collector dissipation at 25° C was investigated. It seems reasonable to characterize the quality of such a driver, working into a load R_L returned to a voltage U, by a quality factor n defined by

$$n = \frac{\text{Voltage swing x Current swing}}{\frac{1}{2}(\text{Collector dissip. in 0 state + Collector dissip. in 1 state})}$$

$$= \frac{2\,[E(1) - E(0)]\;[I(1) - I(0)]}{P(0) + P(1)}$$

For obvious reasons, it is desirable to keep E_{max} and I_{max} to a minimum. For a given swing, this can be achieved by returning R_L to ground (U = 0) and by making E(0) = -E(1) which implies I(0) = -I(1). In order to obtain sufficient speed, it is then necessary to drive the output in push-pull fashion, otherwise, large RC-constants will limit the speed for at least one direction of variations.

The problem is then: design a push-pull driver of the "cathodyne" type (i.e., a collector tied to an emitter, driving the load which is tied to ground) with P(0) + P(1) a minimum. For a push-pull driver, this implies that we must always have one transistor near to saturation and the other one near to cut-off.

This means designing a circuit which keeps a transistor out of saturation, yet allows it to go as near to it as possible. For the transistor which has a fixed collector return, this is no problem. For the other one (see Figure 1), non-saturation can be accomplished by modifying the collector-base feedback diode scheme to include a voltage divider between the feedback point, which is also the input, and the base. This makes the transistor look as if it had a lower, but constant, α and a higher r_b'. The saturation margin $\delta = r_b'(1-\alpha)i_e - \gamma$ where i_e = emitter current, γ feedback diode drop, can then be made equal to a small but positive quantity. Note that

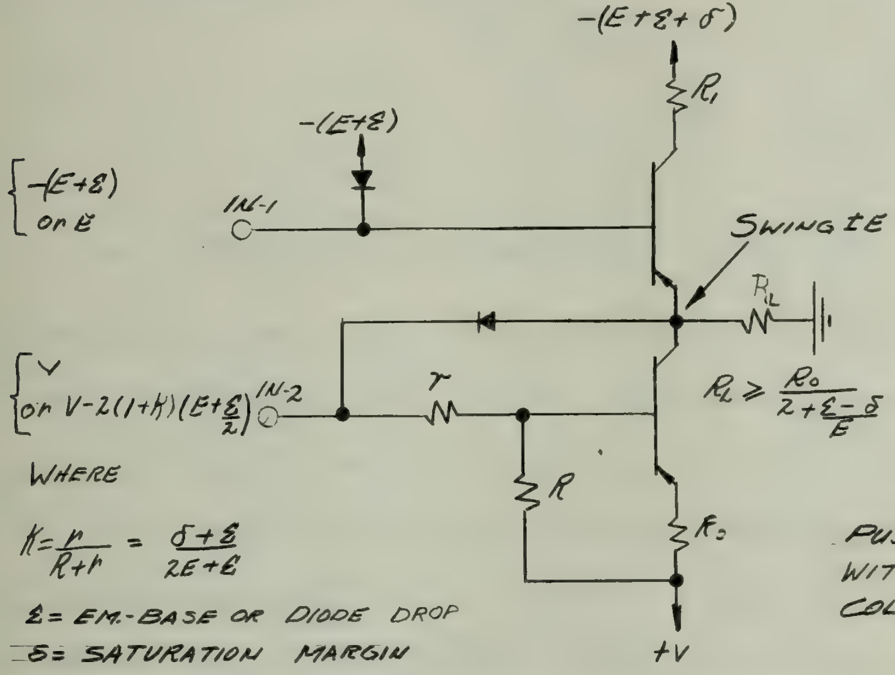
$-(E+\varepsilon+\delta)$
R_1
$-(E+\varepsilon)$
$\left\{ \begin{array}{l} -(E+\varepsilon) \\ \text{or } E \end{array} \right.$
IN-1
SWING ±E
R_L
$\left\{ \begin{array}{l} V \\ \text{or } V-2(1+k)(E+\frac{\varepsilon}{2}) \end{array} \right.$
IN-2
r
R
$R_L \geq \frac{R_0}{2+\frac{\varepsilon-\delta}{E}}$
R_0
+V
WHERE
$k = \frac{r}{R+r} = \frac{\delta+\varepsilon}{2E+\varepsilon}$
ε = EM.-BASE OR DIODE DROP
δ = SATURATION MARGIN

FIG.-1
PUSH-PULL DRIVER WITH SMALL QUIESCENT COLLECTOR DISSIPATION

the increase in input swing necessitated by this circuit is immaterial, as is the fact that the input impedance is lowered. We are only interested in the efficiency of the last stage.

Four flow-gating flipflops (see December Report) were connected in pairs according to Figure 2, the object being to test their speed in a counter of novel design.

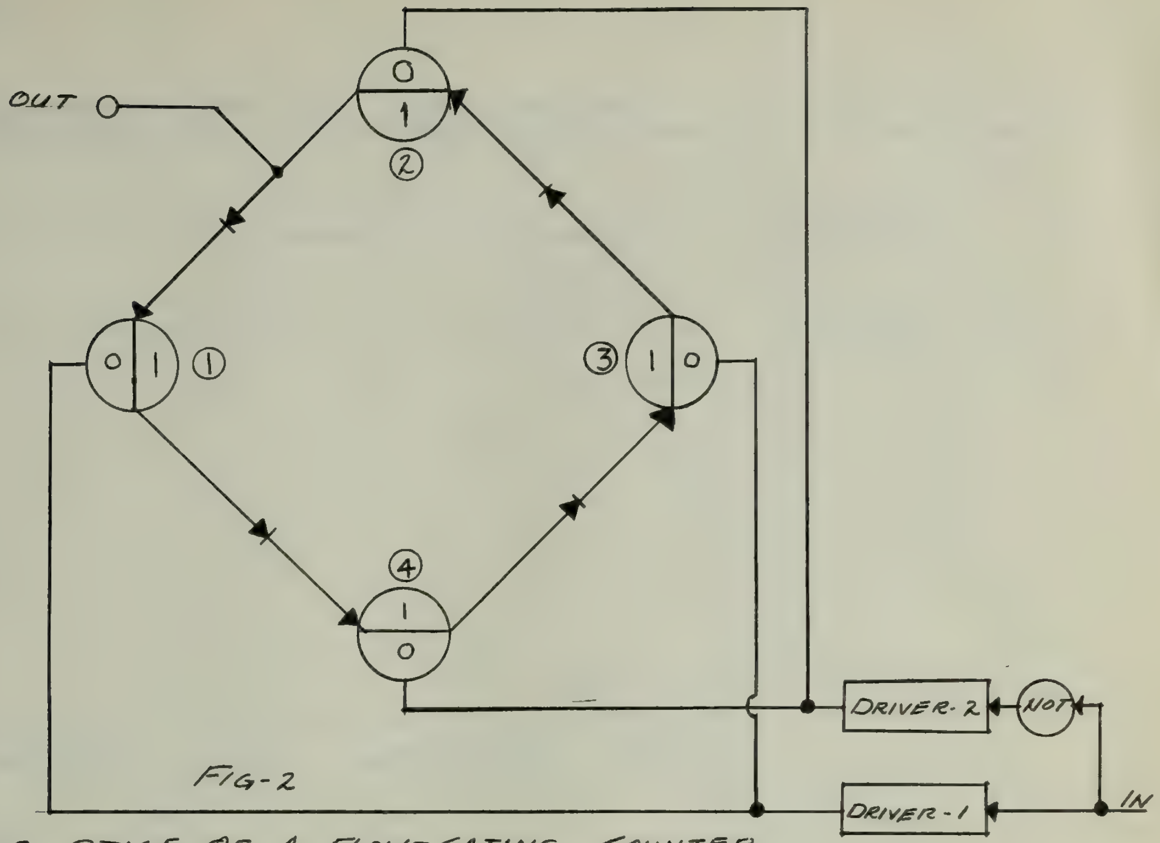

FIG-2

ONE STAGE OF A FLOW-GATING COUNTER

The circuit works as follows: Suppose that when we have a 1 at the input to the first driver, flipflops (1) and (3) are in their "normal", more positive, state, i.e., that they cannot receive information. Due to the NOT circuit, flipflops (2) and (4) are then in the "gating", more negative, state, and information will be gated from (1) into (4) and from (3) into (2). When IN now goes back to a zero, the contents of (2) and (4) will be sent to (1) and (3) respectively. If we put into the four flipflops the initial pattern 0011, we shall observe cyclic shifting. Looking at one of the flipflops (OUT), we see square pulses, the period of which is twice that of the incoming symmetric square wave, i.e., we have a frequency divider. Of course, the device is asynchronous if alternate non-overlapping gating signals are provided by the two drivers.

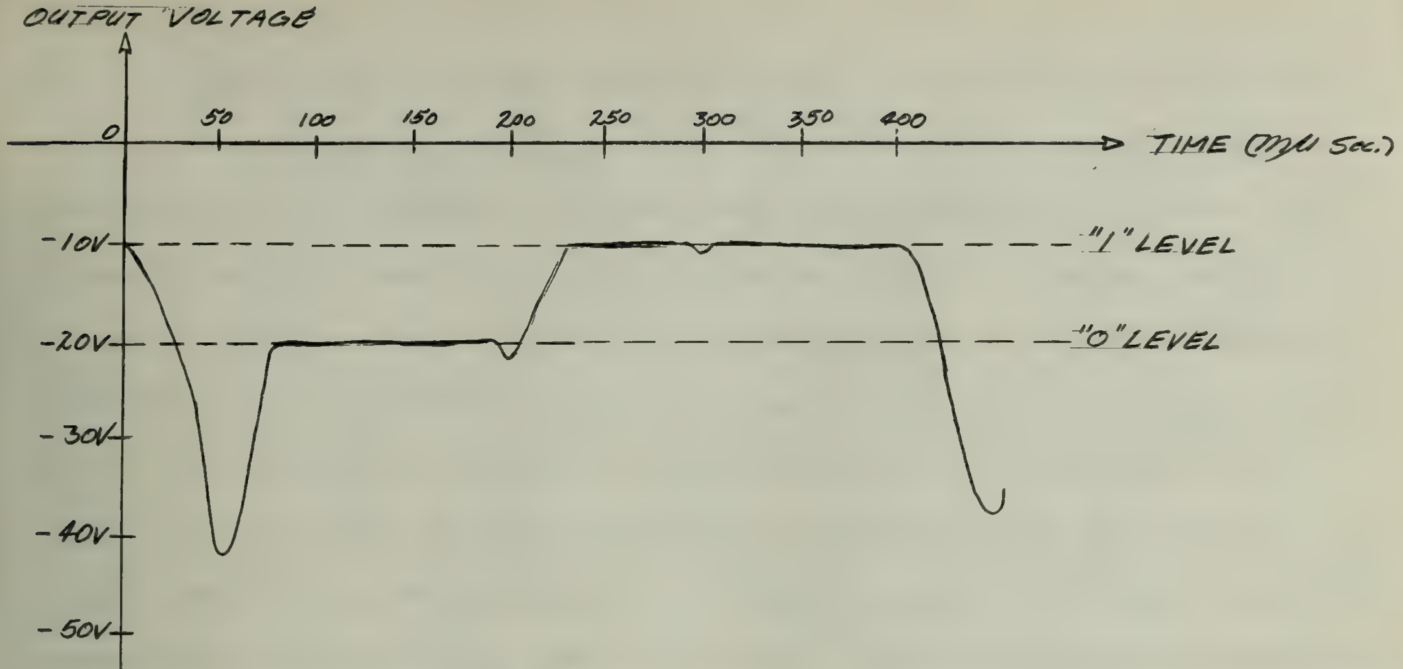

FIG.-3

OUTPUT OF A FLOW-GATING FLIP-FLOP IN THE COUNTER OF FIG.-2. INPUT: 5 M.C. SINE-WAVE

Figure 3 shows the output of a flipflop when the input is a 5 mc sine-wave. Satisfactory operation can be obtained at nearly twice that frequency. This shows that the setting time of a flipflop is less than 50 mμs. Note that the normal output levels, i.e., -10V and -20V are overswung during the gating in of the 0 state. This does not interfere with the transmission of information to another stage since it simply cuts off the transfer diode by a greater margin.

2. Control Studies

Control Design

The design described in Digital Computer Laboratory report number 80, in Chapter 3, has been simplified in the following ways.

a) The shifting number register (M, $\overline{M}$) and the two operand buffer registers (X,Y) are included in the addressing system as R_4, R_5, R_6, and R_7

(B = 4,5,6,7) for short arithmetic instructions. This imposes a very slight restriction on the use of B_4, B_5, B_6, B_7 which can now be used for modifiers and counters, but not for complete addresses. Any number transferred to or from the arithmetic unit is placed in M, so R_4 contains the last operand unless the last arithmetic operation required a shift of the number register (division, floating point add subtract or divide, or generate a power of 2 and add or subtract). $\overline{M} = R_5$ is the register R referred to in report 80, and can be used as an extra temporary register when $(M, \overline{M})$ is not shifted. R_6 refers to the last operand brought from the core memory (one of X or Y) and R_7 refers to the second last operand brought from the core memory. This way of using X,Y has several advantages over that previously described:

> The address registers A_X, A_Y, together with the equipment required to compare an address with the contents of A_X, A_Y is eliminated. This simplifies advanced control, the method of starting up the computer, and the problem of determining what state the machine is in.
>
> The ambiguity about whether the current or past contents of a memory register is referred to, is removed.
>
> The form of the instruction tells advanced control immediately whether or not to read the number from the memory.

b) The manner in which products are accumulated double precision has been simplified. A special instruction "prepare to add product" has the following effect: a factor is transferred to M, and A is assimilated. Then, M is copied to $\overline{Q}$, Q to $\overline{A}$ and A to $\overline{M}$ simultaneously. Then, $\overline{A}$ is copied to A and $\overline{Q}$ is copied to Q. The addition of the product can then be achieved either by one special purpose instruction $(aq) = (mxq + 2^{-51}a) + \overline{m}$, or by two conventional instructions: "hold multiply", and "add $\overline{m}$".

c) The registers R_2,R_3,X,Y,O_1, O_2 together with 12 B-lines (in effect 3 registers comprising B_4-B_7, B_8-B_{11}, B_{12}-B_{15} respectively) could be combined into a single flow-gating unit of 9 x 52 bits with the following facilities:

1. Copy a word from M or the core memory register, or copy a word to M or the core memory register.
2. Read any two consecutive 13-bit groups from O_1, O_2 or the B-registers to advanced control, arithmetic control or the B-line adder.
3. Write from the B-line accumulator to any B-line.

This can be achieved with the aid of 3 bus bars inside of the flow-gating unit (at most, 2 connected to any flipflop) and a decoding system. By adding one extra flow-gating register to this, it should be possible for advanced control to sequence block transfers to or from auxiliary storage on an interrupt basis.

d) The following short instructions would be useful:

Waste (an instruction which does nothing).

Set the contents of the designated B-line to zero.

Add two consecutively numbered B-lines and place the result in the second B-line.

Transfer control inside O_1, O_2 to the position given by B if the accumulator is non-negative.

Add 1 to a designated B-line if the accumulator is non-negative.

e) The following long instructions would be useful:

Modify the next instruction by an address from location b+N, the control group inside that word given by the two C-bits of this instruction.

Transfer to X or Y (this long or short instruction allows an operand to be read from the core memory at a convenient time, to be used later).

The Core Memory Access Studies

The waiting time for a slow main memory may be reduced by the use of some or all of the following techniques:

a) Read several (consecutive or non-consecutive) words from the memory simultaneously.

b) Reduce the number of words transferred to or from the main memory.

c) Use the memory and arithmetic unit concurrently.

A first attempt has been made to obtain meaningful statistics on the influence on (b) of the various features in the proposal in report number 80. A family of computers, each differing from the immediately preceding by the addition of another group of features has been defined, and the Runge-Kutta subroutine was programmed for each.

The features considered were:

a) B-modification.

b) Additional overflow and round-off facilities, and single length and logical shifts.

c) The ability to add double length products, multiply by A, store from Q, multiply without destroying Q, etc.

d) A memory sufficientlv large that separate loops for the 4 steps of Runge-Kutta could be programmed.

e) Provision of extra registers. (R_2 and R_3 proved sufficient.)

f) Short instructions.

g) The ability to execute short loops repeatedly from O_1 O_2.

For n first order differential equations, the total number of memory accesses to advance the variables by one step was:

Illiac	123 + 212n
with (a)	19 + 144n
and (b)	19 + 124n
and (c)	19 + 88n
and (d)	10 + 68n
and (e)	18 + 51n
and (f)	15 + 39n
and (g)	15 + 39n

It is planned to collect more statistics over a wide class of problems, particulary those which make demands on the memory.

3. Core Memory

Reading Amplifier Design. Work on the core read amplifier was continued. The problem of providing a push-pull output from the amplifier to set a symmetric flipflop was found to be rather difficult with the long gate (strobe) signal necessitated by variations in selection driver and sensing signal delays.

The difficulty concerns the tolerance considerations necessary to insure that with no input signal, or even with a 20mv noise signal, the output of the amplifier will not set the flipflop. The amplifier must also have sufficient gain to set the flipflop even with the smallest expected signal, 100mv, and must recover rapidly when overloaded.

A new design is now in progress which uses a single-ended amplifier and a modified flipflop to give symmetric outputs. Nonr-1834(15).

Transmission Delay Measurements. An experiment in core delay time is being conducted on several types of bit cores currently under consideration for the core memory. One thousand bit cores of a given type will be strung on wires

in such a way as to approximate an actual working core plane. The jigs to hold these cores have been constructed and are awaiting the necessary cores.

Core Test Equipment. More versatile magnetic core test equipment has been assembled. The equipment includes

12 variable length transistor pulsers (similar to Dwg M765)
6 vacuum tube current drivers (Dwg S764)
1 three-stage counter (Dwg M770)
1 single-stage counter (Dwg M769)
1 pulse sequence sampler (Dwg M768)

Each vacuum tube driver is capable of being driven from ± 2 volt nominal signals used in the transistor circuits. A. C. coupling and D. C. restoration are employed to separate the higher voltage vacuum tube circuits from the lower voltage transistor circuits. Each driver can produce a current pulse variable is amplitude from 200ma to 750ma with a rise time of approximately 50 mμsec.

Each pulser produces a pulse variable in length from 80 mμsec to several microseconds.

PART II

SWITCHING CIRCUIT THEORY

(This work is supported in part by the Office of Naval Research under Contract N6ori-07130.)

A process has been developed for designing a combinational circuit to produce a given set of switching functions which has a minimum number of NOT elements. The assumption is made that the only other logical elements available are non-inverting (monotonic) switching elements.

An analysis of this process shows that any set of swithcing functions of n inputs can be realized from a combinational circuit containing no more than k NOT elements, where k is the least integer not less than $\log_2(n+1)$.

This process has been used to design a 2^k-1 stage adder which contains k NOT elements, and to design a combinational circuit which simulates the behavior of three independent NOT elements yet contains only two NOT elements. These examples show that the process is of no practical value in circuit design. It is, however, the first instance in which an absolute minimum design process has been achieved for combinational circuits, and may point the way toward other minimum design processes having more realistic criteria of minimality.

PART III

MATHEMATICAL METHODS

1. Hydrodynamic Flows with Shocks (Supported in part by the National Science Foundation under Grant G2794.)

The numerical stability of two systems of second order formulas for numerically integrating the Eulerian form of the one dimensional conservation equations governing hydrodynamical motion was investigated. These were second order systems in that the equations governing the numerical stability involved terms of second degree in Δt. Both of the systems were found to be stable.

2. Monte Carlo Method for Studying Crystals

Some interesting results were obtained with the Monte Crysto program (see December, 1957, Monthly Report, Part III). For the first time two samples, initially containing a random configuration of atoms, spontaneously assumed the pattern of long-range order. Also the specific character of those systems which do not spontaneously assume this pattern of long-range order seems to have been found.

The samples exhibiting spontaneous ordering were found in runs made with a non-zero second neighbor interaction energy; the first neighbor interaction energy is defined by $v_1 = \left(\frac{V_{AA} + V_{BB}}{2} - V_{AB}\right)$ where V_{AA} is the interaction energy for a pair of next-neighbor A atoms, V_{BB} is the interaction energy for a pair of next-neighbor B atoms and V_{AB} is the interaction energy for a next-neighbor pair AB; the second neighbor interaction energy, v_2, is likewise defined for second neighbor atoms. Four samples with an initially random arrangement of atoms were given one parameter value for v_1/kT which should produce

long-range order, and $v_2 = -(\frac{1}{2}v_1)$. Two of these samples did establish a pattern of long-range order; A atoms being on the face centers and B atoms on the corners. The two samples which did not establish this pattern appeared to have two "disordered" planes as described below.

Runs which have been made previously with a value of v_1/kT which should produce long-range order, but with $v_2 = 0$, never did establish long-range order even after as many as 700 iterations. One of these samples has been looked at in detail and it was found that all of the planes of the lattice did show the correct configuration of order but two planes differed in that A and B atoms were interchanged. Preliminary consideration of the results of other runs which did not converge to a pattern of long-range order seem to indicate that this phenomenon is repeated there too. This type of disorder is relatively stable since it represents a configuration energy which differs but little from the ordered configuration. In fact, when $v_2 = 0$, the presence of a plane with A and B atoms interchanged does not alter the configuration energy.

The current results indicate that a second neighbor interaction is necessary to establish the long-range order. However, since two samples did not order even with the second neighbor interaction present, it seems that $v_2 \neq 0$ is not enough to guarantee the establishment of a pattern of long-range order. The nature of the difficulty also indicates that introduction of a small ordered "crystallite" as mentioned in the December Progress Report will not solve the convergence problem. At the present, two courses seem open. One is to increase the strength of the second neighbor interaction although the experimental evidence which exists seems to indicate that the second neighbor

interaction should be rather weak. Another procedure might be to set up a border of ordered unit cells about the crystal to establish a pattern of order. In this procedure the atoms in the border would be treated in a completely identical fashion to the other atoms in the crystal, the only difference being that they would be initially ordered. In future computations the plan is to try these two schemes.

3. Programming (Supported in part by the Office of Naval Research under Contract N6ori-07130)

a) A new matrix multiplication routine has been prepared which uses the magnetic drum for storage of data. When multiplying an (i x j) matrix A into a (j x k) matrix B, the matrix B is held on the drum. Limits on size are given by $ij \leq 10240$ and $j \leq 412$. The correct element of the product matrix is printed regardless of whether or not overflow has occurred during the multiplication process, since the overflow is accumulated in a separate register.

b) A comparison post-mortem for use with SADOI has been prepared and placed in the locked out section of the drum. This program prints the discrepancies between the users program as stored on the drum by SADOI, and as it appears in the memory at the time his program stops.

PART IV

ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

Machine Use

During January specifications were presented for 18 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1090.

1090 Computer. Gaseous Equilibrium in a Star. A system of four ordinary differential equations describing the state of a spherically symmetric collection of gas (representing a star) is to be integrated. Special techniques will be used in the neighborhood of singularities.

1091T Education. Data for three critical thinking tests have been collected for five hundred pupils in four Illinois high schools. Studies will be made of the items of the three tests in an attempt to determine whether they really do measure the same abilities and skills. The items of the three tests will be factor analyzed separately, and a fourth test is to be made up as a composite of some items from all three tests and will also be analyzed.

1092 T Determination of Personality Factors in Psychiatric Patients in Gainsville, Florida Veterans Hospital. After a two weeks' observation period of psychiatric patients by male nurses, they were asked to rate the patients on a five-point scale regarding physical and psychological components. From these ratings, a Pearson product/moment correlation matrix was obtained.

In order to arrive at personality factors inherent in these diagnosed psychiatric patients, it will be necessary to run a centroid factor analysis and an oblimax rotation.

1093 Computer. Feedback Amplifier Plot. The program computes the magnitude and phase of the over-all gain and $\mu\beta$ for a single loop amplifier for which the values and types of corners of the μ and β functions are given. Only first-order corners are considered. The computation is made at each value of a list of ω's provided by the user.

1094 T Rapidly Propagating Brittle Fracture. It is desired to develop an analytic solution for a brittle crack propagating through a flat plate. An analytic solution would give the transient strain response of the plate from which energy relationships could be found and the effect of various parameters investigated. The plate response for an assumed fracture criterion could be calculated and the results compared with test data in an attempt to isolate the factors controlling crack propagation. Attempts to find a mathematical solution to the propagating crack problem have so far been unsuccessful. Therefore a numerical approach is to be investigated in which the plate is broken down into a lattice consisting of a series of rigid bars, deformable nodes, and shear springs.

1095 Physics. Photodisintegration of Complex Elements. Several miscellaneous computations involved in the reduction of data from an experiment on the high-energy photodisintegration of helium, lithium and carbon will be made. Among other things these computations will involve the production of several bremsstrahlung spectra and the computation of a counter efficiency.

1096 T Radiation Power Due to a Source on a Dielectric Rod. The electromagnetic field $F(\theta)$ due to a source on a dielectric rod will be calculated and the radiation power will be obtained by evaluating the integral $\int_0^{\pi/2} \cos\theta \left|F(\theta)\right|^2 d\theta$.

1097 Physics. Relativistic Transformation to Center of Mass System. Energy, momentum, and relative angles of particles in the center of mass system will be calculated for the following high-energy reactions:

$$K + p \longrightarrow K + p$$

$$K + p \longrightarrow \Sigma^{+} + \pi^{-}$$

$$K + p \longrightarrow \Sigma^{-} + \pi^{+} \quad .$$

1098 Sociology. Factors Influencing the Relation between Obligation and Appreciation. In an interview designed to get at the relationship between the subject's perception of the amount of obligation someone is under to do something for them (such as a husband to bring home a gift on no special occasion) and the subject's appreciation toward the other person, a 42-item check-list was included. The subject was told to check each item that applied to the situation (in which obligation and appreciation was related). It is desired to extract the major factors in the checklist with the hypothesis that subjects who perceive the situation differently (as indicated by their factor scores) will tend to relate obligation and appreciation in different manners. Specifically the relationship between obligation and appreciation should be described by some family of curves, having one parameter dependent upon factor scores.

1099 T Mathematics. Algebra Calculations. A study will be made of applicability of digital machines to group-calculations. Schrier relations for some small but unstudied groups will be calculated and an attempt will be made to treat as large a group as time and storage permit.

1100 National Institute of Mental Health. Maternal Patterns. The purpose of this analysis will be to refine a test and to develop scoring keys. A test on maternal attitudes of 200 dichotomous items was given to 202 patients. These items will be grouped into clusters on the basis of inter-item covariances. These homogeneous clusters will form scoring keys. The 202 patients will then be scored on the scoring keys. Finally a matrix of correlations will be calculated among the scoring keys.

1101 T Structural Research. Load Constants for Floor Slab Dynamometers. The equations to be solved are based on calibrations of a special dynamometer which measures the three components of a reaction. Sixteen such dynamometers are to be used to measure column reactions of an experimental flat slab structure. Each component of the reactions will be obtained directly by use of the "inverted" equations.

1102 T Electrical Engineering. Solution of Characteristic Equation for a Source on a Dielectric Rod. This problem is related to the one described under 1096 T and concerns the solution of the characteristic equation of the field which propagates on the dielectric rod.

1103 Psychology. Parental Attitude Survey. A statistical analysis will be made of results of a survey administered to students in child psychology.

1104 Aviation Psychology. Time on Target. This is a preliminary program to calculate Time on Target (TOT) for two parameters, pitch and roll, for up to 116 tolerance bands. It will be used for data generated from human engineering experiments conducted at the Aviation Psychology Laboratory.

1105 T Civil Engineering. Blast Wave Transmission through a Semi-Infinite Elastic Medium: Static Case. Whereas the characteristics of blast waves passing through air are well established, little is known concerning the magnitude and shape of the blast waves which are transmitted through soil. This routine is being written as an upper bound solution to the actual case of blast wave transmission through soil.

In this solution an atomic or hydrogen type weapon is exploded on the earth's surface. The blast wave at a certain range is considered as a plane wave and the horizontal, vertical, and shearing pressures at a given depth in the soil are computed for many successive positions of the blast wave. In this manner a diagram of pressure vs. time may be constructed for various bomb sizes, ranges, and depths. The soil mass is replaced by a perfectly elastic, homogeneous, isotropic medium in which dynamic effects are neglected, i.e., the mass of the soil is considered equal to zero, and consequently the velocity of the blast wave in the soil is infinity.

1106 Structural Research. Computation of the Maximum Response of a Single Degree of Freedom System Due to a Given Earthquake. The purpose of this study is to determine the response of a single degree of freedom system due to any given earthquake as a function of the period, mass and yield resistance of the system.

1107 Electrical Engineering. Boundary Value Problem in Ridged Wave Guide. Normal modes in a ridged wave guide will be found using the standard eigenvalue program.

Table I shows the distribution of machine time for the month of January.

TABLE I

	Hrs:Min
Regular Maintenance	18:32
Unscheduled Maintenance	1:07
Drum Engineering	43:17
R.A.R.	5:21
Leapfrog	46:45
Wasted	:00
Use by Departments	
Computer	99:11
Physics	11:31
Control Systems Lab.	125:15
Structural Research	62:29
Struct. Res. (AF 24994)	18:25
Psychology	19:28
Psychology (Pub. Health 1733)	2:22
Psychology (MD 569)	:20
Electrical Engineering	14:47
Elect. Eng. (AF 3220)	1:21
Chemistry	19:28
Agriculture	22:52
State Water Survey	7:00
Inst. of Communications Res.	3:35
Mech. Eng. (ORD 1980)	1:29
College of Medicine	1:11
Classes	18:24
Demonstrations	1:58
Miscellaneous	24:39
	570:47

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 A.M. and 11:00 A.M., and for a check of its performance between 5:30 and 6:30 P.M. of each weekday. Since the periods between 7:00 and 11:00 A.M., together with certain irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error standpoint to look at the periods between 11:00 A.M. and 7:00 A.M. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between 11:00 A.M. and 7:00 A.M. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. During the 5:30-6:30 period (when the machine is checked) if no errors are found, the time is given to the "running" column. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
1/2/58	19:58	:02	2	(1) Drum failure (2) Drum failure	0	1:10	0
1/3/58	20:00	:00	0		0	:58	0
1/6/58	19:39	:21	2	(1) Drum failure (2) Leapfrog failed, reason unknown	0	3:39	1
1/7/58*	19:48	:12	0		0	:56	0
1/8/58	20:00	:00	0		0	:41	0
1/9/58	20:00	:00	0		0	:49	0
1/10/58	19:59	:01	1	(1) Tapes tore in reader "k"	0	1:07	0
1/13/58	20:00	:00	0		0	:40	0
1/14/58	20:00	:00	0		0	:44	0
1/15/58	20:00	:00	0		0	:39	0
1/16/58	20:00	:00	0		0	:40	0
1/17/58	20:00	:00	0		0	:40	0
1/20/58	20:00	:00	0		0	:50	0
1/21/58	20:00	:00	0		0	:50	0
1/22/58	20:00	:00	0		0	3:24	0
1/23/58	19:33	:27	1	(1) Drum failure	0	:43	0
1/24/58	20:00	:00	0		0	:49	0
1/27/58	20:00	:00	0		0	:39	0
1/28/58	20:00	:00	0		0	:37	0
1/29/58	20:00	:00	0		0	:38	0
1/30/58	20:00	:00	0		0	:51	0
1/31/58	20:00	:00	0		0	:40	0
TOTALS	438:57	1:03	6	*12 minutes engineering, but no error indicated.	0	22:44	1

probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for January.

TABLE III

Drum Failure	4
Reader Error	1
Unknown	1
Total	6

Reports and Seminars

Seminars

"Properties of Logical Nets" by Clinton R. Foulk, January 7, 1958

"Redundant Logical Circuits" by Dr. John G. Tryon, Bell Telephone Laboratories, January 14, 1958

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TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM
PART II - MATHEMATICAL METHODS
PART III - GENERAL RESEARCH
PART IV - ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

February, 1958

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part through Contract No. AT(11-1)-415 of the Atomic Energy Commission. The contract is supported jointly by the Atomic Energy Commission and the Office of Naval Research. In addition, this work is supported through Contracts N6ori-07130 and Nonr-1834(15), both from the Office of Naval Research.

The University of Toronto is participating in this work through staff members of its Computation Centre.

1. Transistor Circuits

The design of high-powered drivers using GF 45011 transistors was pushed farther. In the course of the investigations, novel results were obtained. It turns out that the large signal α (called A) of these transistors is a linear decreasing function of the emitter current I_e. This empirical result can, at least partially, be backed up theoretically. Figure 1 gives the base current I_b as a function of I_e for five random samples, the collector-base voltage V_{bc} being -1v and the α at 10 ma equal to .98. Comparing sets of curves for other values of V_{bc} and other alphas, it seems that (at least for the small collector voltages we are interested in for drivers) the following expression for the base current I_b obtains:

$$(1) \qquad I_b = \frac{\sigma_o I_e^2}{V_{bc}}$$

Here, σ_o is a constant which depends upon the transistor. Its average value (for currents in amperes, voltages in volts) is 5Ω for GF 45011 transistors. It seems to be independent of the small signal α.

Defining A, B and Γ by

$$(2) \quad A = \frac{I_c}{I_e} \qquad \text{(large signal } \alpha\text{)}$$

$$(3) \quad B = \frac{I_c}{I_b} \qquad \text{(large signal } \beta\text{)}$$

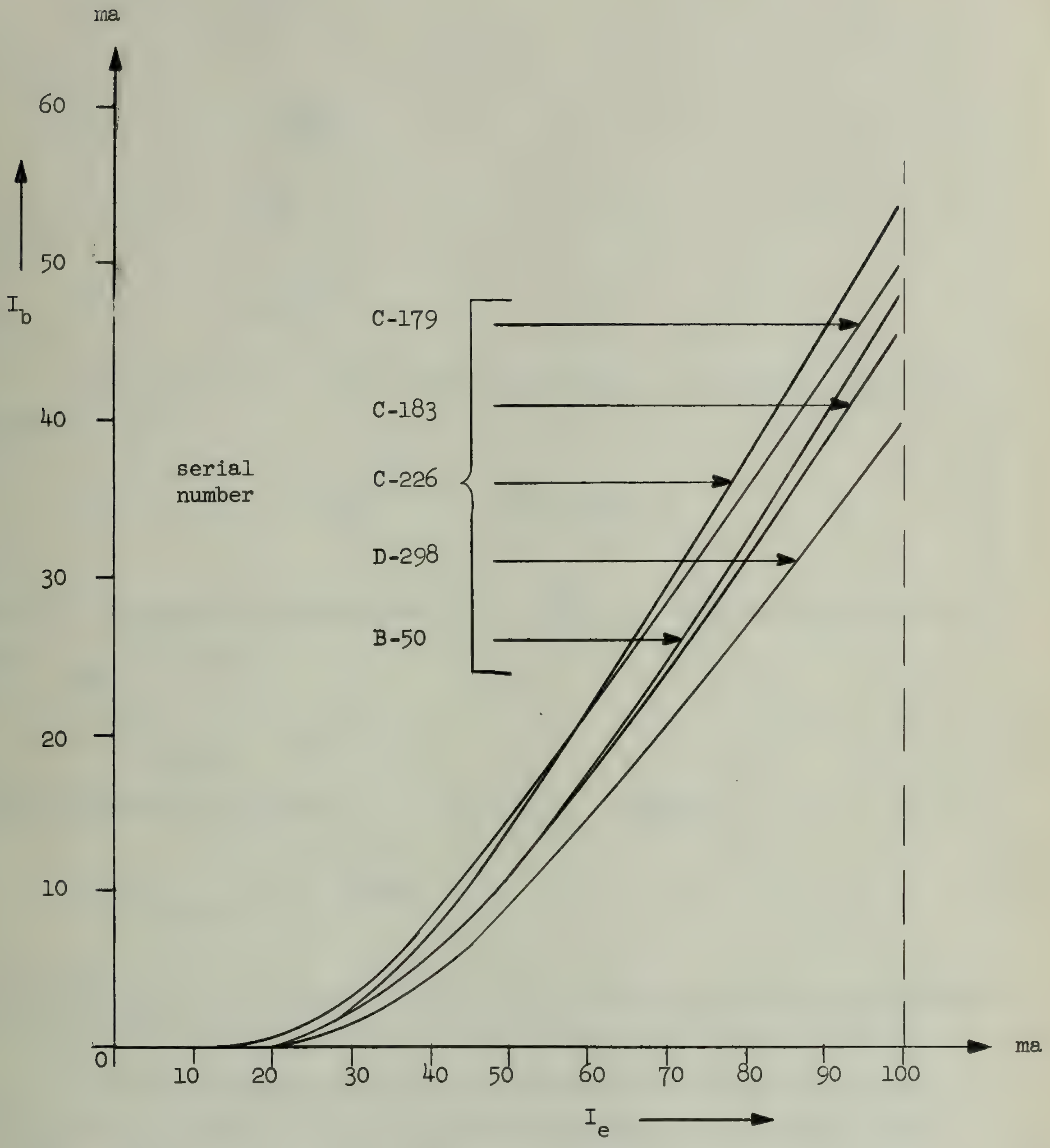

Figure 1

I_b vs. I_e for GF 45011

Transistors (V_{bc} = -1v, α at 10 ma = .98)

$$(4) \quad \Gamma = \frac{I_e}{I_b} ,$$

we obtain

$$(5) \quad A = 1 - \frac{\sigma_o I_e}{V_{bc}}$$

$$(6) \quad B = \frac{V_{bc}}{\sigma_o I_e} - 1$$

$$(7) \quad \Gamma = \frac{V_{bc}}{\sigma_o I_e} .$$

Expressions (5) ... (7) lead to interesting consequences. Take for instance (5). By (2)

$$(8) \quad I_c = I_e - \frac{\sigma_o I_e^2}{V_{bc}} \qquad \text{(see Figure 2)}$$

meaning that I_c reaches a maximum when $I_e = \frac{V_{bc}}{2 \sigma_o}$. This maximum collector current $I_{c\ max}$ is given by

$$(9) \quad I_{c\ max} = \frac{V_{bc}}{4 \sigma_o}$$

but the collector dissipation $P_{max} = V_{bc} I_{c\ max}$, therefore

$$(10) \quad I_{c\ max} = \frac{1}{2} \sqrt{\frac{P_{max}}{\sigma_o}}$$

For a GF 45011 this means that at 200 mw we cannot exceed under any circumstances 100 ma of collector current. The corresponding V_{bc} is 2 v and I_e = 200 ma.

Another interesting question is, "Where is the break-even point for emitter followers defined by the I_e^* for which the total I_b of two paralleled units beomes equal to the I_b of the lower-powered transistor in two cascaded units?". This leads to the condition

$$\Gamma (I_e) \, \Gamma \left[\frac{I_e}{\Gamma(I_e)} \right] = \Gamma \left[\frac{I_e}{2} \right]$$

or, using (7)

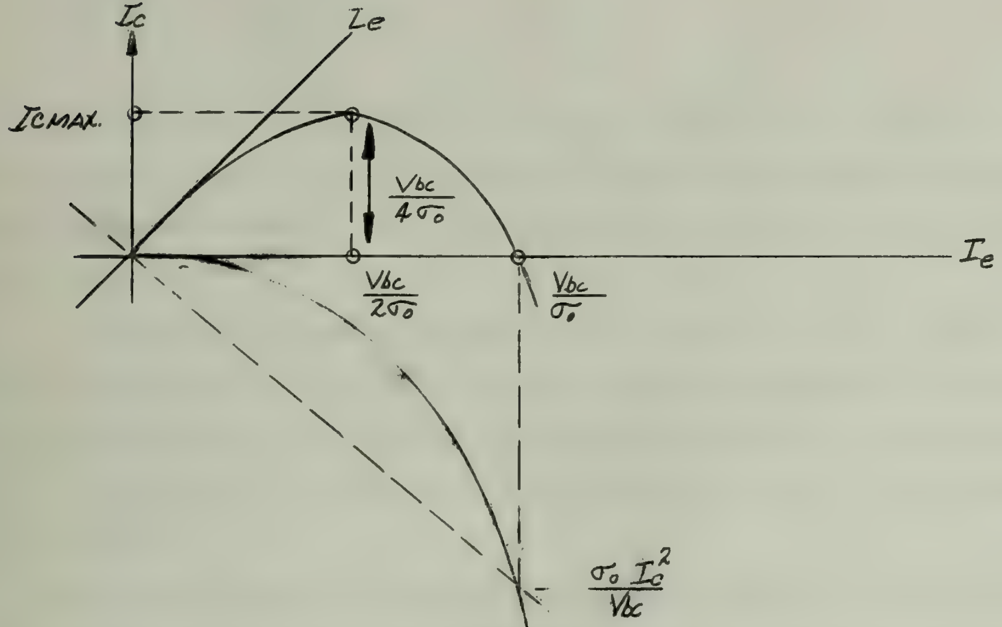

Figure 2

I_c vs. I_e for GF 45011s

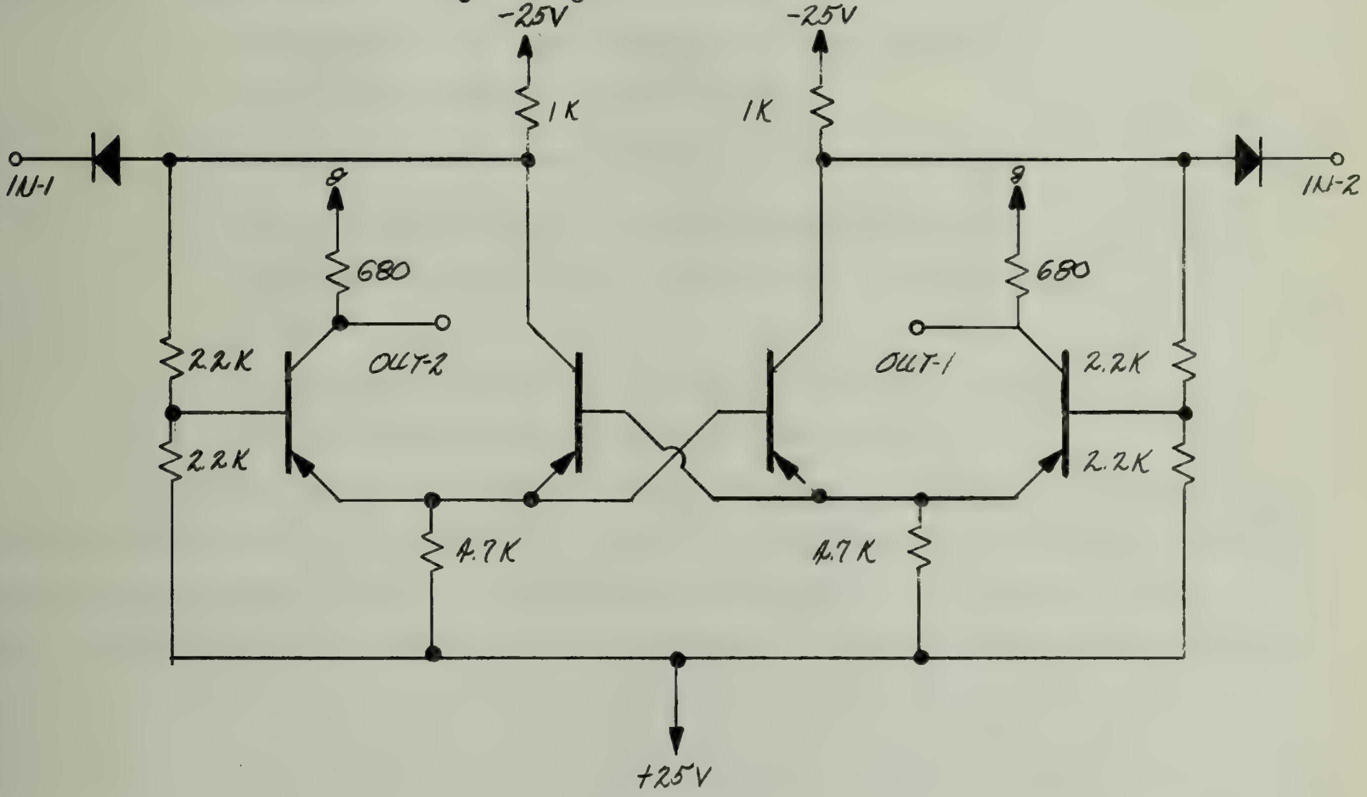

Figure 3

Emitter-Base Crosscoupled Flipflop with Collector Gating (g = -18v normal, -27v for "gate out")

$$(11)\quad I_e^* = \frac{V_{bc}}{\sqrt{2}\,\sigma_o} .$$

It can also be shown that if $I_{c\ max}$ is defined by (10), the cascading of two units still leads to a lower driving current than a parallel arrangement. In view of these new facts, it will be possible to design more efficient drivers in the near future.

A program was started to measure more precisely the factors which affect switching speeds in a simple inverter circuit: impedance, overswing, constant current emitter vs. low-bias emitter, cutting-off of the emitter junction, etc. Preliminary investigations show that not too much can be gained over our present designs.

The idea of using emitter-base crosscoupling (as described in the September, 1955, Progress Report) was taken up again. However, very important modifications were made:

(1) The emitters are now returned to a high voltage to provide constant current driving.

(2) The inputs are now the collectors of the amplifiers.

(3) The outputs are taken from the collectors of the "emitter followers" after insertion of a small load resistor.

(4) The control voltage for "gating out" is the supply of the "emitter followers" mentioned above.

Figure 3 shows the layout of the new circuit. Note that corresponding INs and OUTs are not only in phase, but also that the OUTs are last moving points for negative triggers (used exclusively for this circuit). Operation times of less than 20 mμs were obtained for this flipflop. It should be mentioned that one can just as well control the other two collector supply voltages, and, thus, use "gate in" signals. A system in which both methods of gating are combined is being tried out. This will greatly simplify gating with a common bus system.

(N. Johnson, S. Ray and N. Wiseman)

EXCLUSIVE OR Circuit. A tolerance design was done on a three-transistor EXCLUSIVE OR circuit. When the circuit was tested, it was found that operation times of the order of 25 mμs were possible, conditional on the availability of a fast diode. Attempts are being made to obtain suitable fast diodes.

(K. Smith)

2. Control Studies

Floating Point. A single length floating point number x in the core memory is one word consisting of a 43-bit fractional part x_f and a 10-bit base 4 exponent called x_e, and has the value

$$x_f \cdot 4^{x_e} .$$

A base 4 exponent is preferable to a binary exponent because base 4 shifts are twice as fast as binary shifts and are already required in the AQ register for fixed point multiplication and division.

A floating point number held in the arithmetic unit or in one of the fast-access registers consists of a 53-bit fractional part held in the register, itself, and a 10-bit exponent held in a fixed associated B-register. Thus, intermediate results are held to higher precision, no special end connections are required in the AQ register, and exponent arithmetic is done with the B-adder.

A number is called standardized if $\frac{1}{4} \leq |x_f| \leq 1$. When an unstandardized number is stored, the leftmost zeros or ones indicate the relative precision of the number. For example, the difference of two nearly equal numbers has a very small fractional part, and no accuracy is gained by standardizing it. Dr. N. Metropolis has suggested a non-standardizing type of floating point arithmetic in which the result of addition or subtraction is not scaled unless overflow occurs, and the expected value of the fractional part of a product or quotient should be equal to the smaller of the fractional parts of the two operands. Thus, an estimate can be obtained of the effect of cancellation errors (as opposed to round-off errors) on the final answers.

This type of arithmetic is not appropriate when errors are not independent (for example, iterative procedures) when the statistical variation in the number of significant figures due to multiplications and divisions is too great, or when it is desired to minimize the effect of rounding errors. However,

non-standardized arithmetic is faster because fewer shifts are required; it is a promising tool for controlling the accuracy of floating point calculations; and for standardized arithmetic one has only to standardize each number before storing it.

Multiplication requires that the fractional part of larger absolute value be standardized before multiplication. If this factor lay between 1/2 and 5/8 in magnitude the product is shifted left one place, base 4. The proposed fixed point division scheme contains a standardizing procedure which can very easily be modified to generate a number of significant digits in the quotient equal to that of the smaller operand.

Two types of round-off are required. When a number in the AQ register is copied to a fast register or used as a factor in multiplication, it is rounded to 53 bit precision by inspecting the first non-sign digit of Q. When the contents of the accumulator is to be packed and stored in the core memory, the least significant 10 bits of A are inspected to determine the round-off in the eleventh place. If the round-off required is exactly one-half (a frequent occurrence which can cause serious bias in floating point unless precautions are taken), the eleventh digit is forced to a one.

When an exponent underflows (usually as the result of multiplication or division), the number is replaced by 0×4^{-512}. The same result is obtained if an attempt is made to standardize a number with zero fractional part. However, in unstandardized arithmetic, a zero fractional part with a high exponent can occur, which usually means a large number undetermined by the calculation. After standardization, the number of shifts required is held in a B-line.

A double precision floating point number in the core memory consists of two words with an exponent difference of 21. Instructions are provided to add or subtract a number to the double-precision contents of AQ. These make it possible to do all elementary operations double precision without undue loss of time.

Further details are contained in Digital Computer Laboratory File No. 235, "A Proposal for Floating Point Operations for the New Computer", by Roger Farrell.

(R. Farrell and D. Gillies)

Input-Output and Auxiliary Storage. The following equipment is under consideration:

A magnetic drum (or drums) with a capacity of about 50,000 words, an average random access time of 8 to 15 ms, and parallel storage so words may be recorded or played back at the rate of one every 6 μs.

About 5 magnetic tape units, each with 16 to 20 channels across a 1-1/4 inch tape with a packing density of 300 bits/in, a speed of about 150 inches/sec and a start/stop time of 2 ms or less. A 2500 ft. reel would have a capacity of about 2 million words, and recording or playback would require about 80 μs per word.

A perforated-paper-tape reader with a speed of up to 2000 rows per second.

A line printer with between 50 and 120 columns which can print about 2 lines per second.

Other equipment such as a cathode ray tube output with duty cycle too low to seriously affect the control design.

Paper tape is suggested for the preparation of problems because of economy, high speed, and relative ease of corrections. For those problems requiring the greatest temporary storage, at least 3 magnetic tape units are needed, since one can be used for each of reading, writing, and rewinding. Furthermore, it is advantageous if very few problems require that magnetic tapes be changed during the problem. Studies are under way to see whether 10 million words (5 reels) is sufficient, and also to estimate the average duty cycles of drums and tapes to determine what advantage may be gained from overlapping input-output with calculation, and possibly using several units simultaneously. Parity checks are desirable for words on the drum, and essential for blocks of information on magnetic tape. It is suggested that the library of subroutines and active programs be stored on a small portion of one magnetic tape--available to the input routine but suitably protected from the programmer.

Automatic code checking seems to require three things:

(a) a small portion of the core memory to which control is transferred whenever an illegal instruction is encountered,

(b) a periodic control transfer (perhaps once every 10 seconds) to this portion of the core memory in order to detect when a program has run too long and may be in a loop,

(c) the ability to sense the state of the machine (the contents of all fast registers, indicators, and the control counter) and to restore these to their original state to continue executing the program.

The possibility of having no off-line conversion, but using the core memory and magnetic tape as a buffer between paper tape and the input routine, and between the output routine and the line printer, is being studied. It is felt that larger reels of magnetic tape would be useful for scientific calculation.

(C. Gear and D. Gillies)

Programming Studies. The memory access problem, that is, the ratio of arithmetic time to memory time, and the efficiency of overlapping these times was studied for library routine F1 (Runge-Kutta) and the triangularization of a matrix, such as in library routine L6. The principle concern now is to reduce the number of memory references to make it possible for the arithmetic unit to have a duty cycle of nearly 100%. As was reported in the January Technical Progress Report, the number of memory references in F1 can be reduced by 60%. A similar study of L6 which has been partially completed indicates that the reduction is of the same magnitude. Further studies are planned.

The following points have been considered with regard to input, output and auxiliary storage:

(1) the average time wasted between successive elements (blocks of words or individual words) should be small;

(2) the transfer instructions should not occupy too much of the control unit's time;

(3) the block size should be sufficiently small for flexibility.

The proposal which meets, in part, these requirements is a program-interrupt system where each input-output unit would interrupt the current machine operation after each block has been transferred. The interruption would be about 4.5 mμs long and would enable the programmer to specify the next operation for the given

unit. The only register in the arithmetic unit disturbed during transfers would be a third order register devoted to transfer operations. Any number of input-output devices could be run simultaneously (up to the limit set by the core speed). The basic details of the proposal are as follows: the programmer will have at his disposal a 13-bit register, B_{ok}, which he can set as he pleases. When he instructs a tape unit (or other on line equipment) to obey an order, he may also specify that he desires the unit to interrupt his program on completion of that order. In that case, the unit will, on completion of the order, cause, after the current order in control has been obeyed, the next order to come from the location specified by the sum of B_{ok} and a number determined by the unit he is using (fixed for all time). Since it is proposed that transfer orders have a register of their own, if this next order is a transfer, it will not affect the rest of the control. Also, transfer orders will be able to specify a core address to be stepped, and should this location now hold 0, to change it to a non-program interrupt order. Its use is best exhibited by example.

Example To transfer p blocks from the tape unit N to core locations n, n + 1, ... n + bp - 1, where b is the block size. Register B_{ok} is assumed set initially by programmer.

---

previous parts of program

....

Order(s) Set least sig. 13 bits of loc. m to -b

Read from tape unit N a block into loc n, ...
Program interrupt at finish. Step least sig.
13 bits of loc. m by 1 (could be performed in the
B adder) and if now 0 do not program interrupt.

Continuation of program.

In location N (B_{ok}) + F (Tape unit N) is the order

Read 1 block from tape unit N into core
location now held in address register (which
will be one more than the last loc. written in) et. seq.,
Increase least sig. 13 bits of mem loc. m by 1
and if now 0 do not program interrupt, otherwise do.

Since the order from this location is so obtained that the contents of the order counter are not disturbed, the control will immediately return to the main program.

(C. Gear)

3. Core Memory

Using the building block units described in the January, 1958, Technical Progress Report, a system for evaluating cores on the basis of a 3 to 1 current selection ratio using 2 cores per bit was assembled. With this system it has been possible to provide a systematic measurement of turnover time, peak signal amplitude, effect of disturb currents, etc. This study has been made on cores manufactured by General Ceramics, Telemeter Magnetics and RCA. The cores tested included half-currents in the range 30 to 450 ma.

The data acquired will be used in conjunction with core delay and associated switch core data in the selection of the bit core type to be used in the final memory unit. (K. Smith)

4. Test Equipment

The diode reverse recovery test set has been finished and tested. It is intended to serve as an ever-ready bench tester of diode recovery characteristics. It includes a relay pulser and means of statically measuring the soak current and reverse recovery voltage. The Tektronics #.517 scope and probe are used externally for display; a means of quick connection of this apparatus has been provided.

The over and under voltage monitoring circuit has been perfected after initial difficulty due to operation on short term "noise" pulses. The version made is equipped to monitor two positive and three negative voltages in the range 1/2 to 30 volts. The acceptable voltage tolerance is of the order of ±10% which should be acceptable for most purposes. This range could easily be tightened if the maximum number of inputs were reduced.

This device is powered by plus and minus volt supplies which are assumed to be available externally. The operating time was measured to be about 10 ms. (K. Smith)

5. Input-Output and Auxiliary Storage

During the month of February, information was collected on possible input-output and auxiliary memory devices for the new computer. Letters were written to manufacturing concerns regarded as possible suppliers of such equipment and to various individuals known to be active in the development of such equipment and related techniques. Much useful information has been received to date; however, replies to the second round of more detailed inquiries have not yet been received. Top priority has been given to the question of magnetic tape recorder characteristics, though much incidental information on magnetic drums and various magnetic recording heads has been collected.

Summary of Tape Recorder Characteristics. The following list summarizes much of the available tape recorder information. In interpreting this information, the following should be borne in mind: the more desirable values of the variables listed may not be compatible in any one machine. The uncertainties here implied will be removed as answers to the more detailed questionnaires are received from the manufacturers. In general, the more conservative values for any variable are regarded as being very easy to attain--any one of several manufacturers could supply machines with such characteristics. The values at the other end of the scale, however, should be regarded as probable limits imposed by the present state of the art; it would probably be extremely difficult to build a machine having these characteristics.

packing density	100 - 1300	bits/inch
tape width	0.5 - 1.25	inches
tape speed	30 - 150	inches/second
start-stop time	≥ 1.5	ms
writing current	1 - 10	ma
number of channels	≤ 20	per inch of tape width

Some data rates have been calculated below for various combinations of packing density and tape speed, based on the assumption that three rows of bits will be required to represent one word.

packing density (bits/in)	tape speed (in/sec)	word rate	
		(wds/sec)	(ms/wd)
200	60	4,000	250
200	120	8,000	125
500	60	10,000	100
500	120	20,000	50
1,000	60	20,000	50
1,000	120	40,000	25

While high data rates are desirable, it may be that increasing the rate is attended by practical difficulties which may increase at a rate much greater than that of the data rate. Two possible instances are discussed below for illustration.

Dust particles on the tape are frequently cited as troublesome when high density recording is attempted. With low packing densities, the tape area assigned to any one bit may be considerably greater than the size of any reasonable dust particle. In this event, it is likely that the presence of the particle will go unnoticed. At densities where bit area and particle size are comparable, the tape may be lifted from the head for an interval corresponding to one bit, though adjacent channels are rarely affect. If the tape is now regarded as moving at high speed, the tape may tend to "float" once separation is established, and several bits may be missed, not necessarily all in one channel.

At low tape speeds, tape skew is due largely to the tolerances of the tape guides. Transverse motion of the tape may tend to make the bits of any given row across the tape arrive at the reading heads at slightly different times. Packing densities must be low enough that this timing error, for channels farthest apart on the tape, is some small fraction of one bit period, so that the reading head never has the opportunity to read parts of two rows simultaneously. Higher packing densities require closer tolerances.

In addition to allowing slight transverse tape motion in a tape guide, it is possible that all guides will not be aligned perfectly with respect to the "ideal" tape path. Considering this alone, any given machine, once assembled, should be expected to pull the same portion of a tape across the same portion of the head on every pass. However, there may be differences between machines in this respect--and the characteristics of a given machine might change if it is taken apart and re-assembled for periodic maintenance. It is considered a distinct possiblity that the higher packing densities can be achieved only by playing back a tape through the same machine on which it was recorded.

Tape skew error may be aggravated by high tape speeds. The tape is flexible and elastic and tends to flutter as it is pulled between supports. This flutter is not necessarily uniform across the tape, and, thus, may tend to increase skew at the recording head.

Magnetic Drums. Less information on magnetic drums has been received than is the case with magnetic tape units. The brief summary below should be interpreted with reservations similar to those mentioned above for magnetic tape.

drum speeds	180 - 6,000 rpm
packing density	50 - 1,000 bits/inch
storage capacity	up to 15,000,000 bits or 300,000 words
writing current	40 - 500 ma
random-access time	5 - 180 ms
tracks	up to 300

Of those drums for which literature has been received, there seems to be very little variation in data rate between drums, with the exception of some very small high-speed drums of very low capacity. However, there are large variations in access time, total capacity, and packing density.

Most drums seem to fall into two classes: those like the present Illiac drum, where head-to-drum spacing is maintained by mechanical bearings; and drums in which the heads are separated from the recording surface only by a film of fluid. The latter class is characterized by high packing density and low speed as well as long access times.

For illustration, the Illiac drum has a random-access time of about 8.5 ms and a capacity of about 10,000 50-bit words. This drum has a packing density of approximately 100 bits/inch. One available drum, with spacings maintained by a film of oil, has a random-access time of 180 ms, a capacity of about 300,000 words, and a packing density of over 1,000 bits/inch. Both drums, however, have nearly the same data rate: roughly, 8 and 7 microseconds per word, respectively, assuming that the number of bits read in parallel is just the number of bits in a word.

Other Devices. Information has been requested on Bell Laboratories' "Twistor" memory device, as well as Potter Instrument Company's "Miniram", a device for handling several tapes in parallel at high speeds.

(R. Cummins)

PART II

MATHEMATICAL METHODS

1. Iterative Methods for Solving Systems of Linear Equation
(Supported in part by the Office of Naval Research under Contract N6ori-07130)

Work continues on the study of the choice of the matrix H in the iterative method for solving the equation

$$x_{i+1} = Gx_i + Hy$$

for solving the equation

$$Ax = y$$

where

$$G + HA = 1.$$

As was pointed out in the November, 1957, monthly report we have

$$x_{i+1} - x = G(x_i - x).$$

If we define

$$\eta_i = \sum_{k=0}^{i} a_{ik} x_k \qquad \sum_{k=0}^{i} a_{ik} = 1$$

that is, if the η's are averages of iterates, then

$$\eta_i - x = P_k(G)(\eta_o - x)$$

where

$$P_k(G) = \sum_{k=0}^{i} a_{ik} G^i$$

and thus are polynomials of degree k in the matrix G. A measure of effectiveness of an iterative method for solving a system of linear equations then involves a choice of a matrix H (that is G) and a set of polynomials $P_k(Z)$ such that

$$\operatorname*{Max}_{Z \in R} |P_k(Z)|$$

is a minimum where Z ranges over the set of values which may occur as proper values of the matrices G.

It has been shown in a paper by Varga (SIAM 5 pp. 39-46, 1957) that over the class of matrices $\{G\}$ restricted only by the condition that the proper values are complex and be inside or on a circle of fixed radius, then the best choice of $P_k(Z)$ is

$$P_k(Z) = Z^{\epsilon} .$$

That is, averaging of iterates is not advisable. For this reason attention is being given to methods for determining symmetric matrices G. At present methods involving alternation of direction of applying the iteration procedure to the components of the vectors x_i are being investigated. (G. Golub)

2. Einstein-Maxwell Field Equations (Supported in part by the National Science Foundation under Grant G2794.)

Recently, H. Takeno (Tensor 7, pp. 97-102, 1957) has shown that for a space time admitting plane symmetry the system of equations consisting of the Einstein field equations,

$$R_{ij} - \tfrac{1}{2}g_{ij}R = -kT_{ij},$$

where

$$T_{ij} = F_i{}^k F_{kj} + \tfrac{1}{4}(F^{\ell m}F_{\ell m})g_{ij},$$

is the Maxwell stress energy tensor defined in terms of the anti-symmetric tensor F_{ij} satisfying the Maxwell equations

$$\frac{1}{\sqrt{-g}} \frac{\partial}{\partial x^i} (\sqrt{-g}\, F^{ij}) = 0,$$

and

$$F_{ij;k} + F_{jk,i} + F_{ki,j} = 0,$$

but are not restricted to be invariant under the group describing the plane symmetry admit solutions depending on time. The question as to whether this is due to an accidental choice of coordinates or not was investiaged. It has been shown that the

Killing equations in the space-times considered by Takeno do not admit a time-like group of motions. Hence, the time dependence of Takeno's solutions cannot be removed by a coordinate transformation, and the solutions represent electromagnetic and gravitational radiation. (S. Patnaik)

PART III

GENERAL RESEARCH

Alpha-Alpha Scattering (See 7 of November, 7 of December, 2 of January, Phys. Rev. 96 , 1333 (1954), Phys Rev. 109, 850 (1958)).

It will be recalled that 9 alpha-alpha scattering runs between 23.1 MEV and 38.4 MEV had been obtained from Gibson of Birmingham and CERN, and 10 runs between 37.6 MEV and 41.2 MEV from Farwell and Yavin of the University of Washington. Original attempts to analyze this data were met with poor success due to some unfortunate manipulations and mislabelings of the original program tapes and due to the fact that the analysis was begun with Gibson's 29.8 MEV data which was too far from the existent Illinois runs to permit good extrapolation toward reasonable initial guesses to begin the analysis. After the receipt of Gibson's 23.1 MEV and 27.6 MEV data, this connection became possible. It was then noted that Gibson's 29.8 MEV data yielded an ϵ (= root-mean-square fitting error) so large as to render the data suspect. The same remark applies to his 35.1 MEV data. Just subsequent to noting this, Gibson wrote saying he had discovered errors of as much as a factor 2 certainly in the 29.8 MEV data, and probably in the 35.1 MEV data. It is hence not surprising that the project led to frustration in its early phases since the analysis was first attempted on the 29.8 MEV data.

It now appears more probable that the program is still useful and valid in these higher energy ranges. To date, all 9 of Gibson's and 4 of Yavin's runs have been processed. The results seem reasonable and are available to those interested.

(J. Snyder)

PART IV

ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

Machine Use

During February specifications were presented for 18 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1108.

1108 T Civil Engineering. A Multi-Degree of Freedom "Shear-Beam" Type System with Relative Damping. A slight modification of program 462 has been made. The purpose of this change is to attempt to (approximately) reproduce the elastic wave propagated through a small diameter cylinder of soil. It is believed that by trying several assumptions as to the nature of the acceleration, several coefficients of damping, and various types of inputs that a relatively accurate and simple method of calculation suitable to use on a desk calculator may be obtained.

1109 T Physical Education. Prediction of Psychological Variables. This is a thesis problem which is investigating the relationships between physiological and psychological variables. Some of the physiological variables are systolic blood pressure, pulse rate, reaction time, and endurance hops. Some of the psychological variables consist of certain projective tests and attitude tests. The first stage of the statistical analysis will be an inter-correlation of the variables by the means of the K-8 routine. The next stage will be the selection of predictor and criterion variables to be used in multiple regression analysis, using the K-14 routine.

1110 Civil Engineering. Earth Slope Stability. The immediate purpose of this program is to calculate the stability of the embankment for a roadway. Factors of safety for various slides are computed and the minimum of these is taken as the safety factor for the roadway. Eventually the parameters of the configuration will be varied to obtain an optimum design.

1111 T Music. Music Transcription. This is a study of the processing of musical and musicological information by means of computers. Its first part will be the converting of various types of coded input derived from a number of musical sources to a standard machine representation which can be utilized for sorting, analysis and for musical typewriter printout. In connection with this last item, means are currently being investigated for acquiring or constructing a musical typewriter activated by punched tape. This is intended to be the first of several projects to be supported by the Graduate College and the School of Music to study the applications of computers to musical problems.

1112 Electrical Engineering. Periodicity in Fading of Moon Signals. The problem is to find periodicity in the fading of signals received from the moon. The signal amplitude is sampled either every second or if the receiving dipole is being rotated, the signal is sampled once per rotation, approximately every 12.5 seconds. The Illiac may be used in finding the autocorrelation function corresponding to these data samples. The information thus obtained about the fading periodicity may then be compared with that available in the literature in order to find out whether or not the two are comparable. If necessary more refined equipment can then be built in order to obtain better results.

1113 T Electrical Engineering. The Theoretical Study of a Slot in a Biconical Waveguide. The electromagnetic field that exists in a slot cut into one of the walls of a biconical waveguide will be found. By expressing the field in infinite series of normal modes and matching the boundary condition that the magnetic field is continuous across the slot, the coefficients for the terms of the infinite series may be found.

1114 Structural Research. Dynamic Analysis of a Shallow Spherical Shell. It is desired to make an analysis of the response of a thin spherical shallow shell when subjected to external dynamic forces.

The shell model divides the surface into tapered beams which are bound by diametral meridians and parallel circles. A continuous medium is approached by allowing the angle between two consecutive meridians and the distance between two adjacent parallel circles to approach zero. This approach is limited only by the storage capacity of Illiac.

The dynamic analysis itself consists of an iterative procedure similar to relaxation. During each cycle the radial acceleration of each point is assumed. Using N. M. Newmark's "Beta Formulae" for integration, the velocity and displacement are obtained. With these data the internal forces can be calculated. The radial resultant of these forces then produces the actual acceleration. This procedure is repeated until the assumed and calculated accelerations converge to the true value.

This cycle is repeated for each increment of pressure loading until the pressure data tape is exhausted. The final step will be to print out the desired information stored in the memory.

1115 Chemistry. Calculation of Wave Functions in Systems of Chemical Interest. This is a preliminary study for detailed computation of the χ functions in systems of chemical interest. For the present one-dimensional S-equations are examined with different potential functions. The one-dimensional S-equation is converted into a set of difference equations

$$\chi_{i-1} = \left[2 + \Delta^2\alpha^2(\omega - v_i)\right] \chi_i - \chi_{i+1}$$

and successive values of χ's are calculated by the repeated application of the above formula. Two initial values of χ and Δ, α, ω are given. v_i is calculable from the potential energy function of interaction which is given.

If the one-dimensional cases give promising results, the method will be extended to the three-dimensional cases.

1116 T Mining and Metallurgy. Capillary Pressure Mechanisms. This research synthesizes porous media by use of computer techniques in order to investigate, step by step, the mechanisms causing capillary invasion of porous media.

A square network of 312 pores is set up by coding methods so that each pore can be looked at at each step of the capillary invasion process. Three questions are asked about each pore:

1) Does the pore contain water?
2) Is the pore large enough to be invaded?
3) Is there an entry path for oil?

Each of these questions can be answered by a yes or no ($\pm$) answer. When each pore has been looked at and the three questions asked, the problem is advanced to the next stage and the process is repeated.

1117 T Chemistry. Single-Center Wave Functions. The solution of the Molecular Schroedinger equation is to be approximated by a linear combination of hydrogen-like wave functions on a single-center with coefficients chosen appropriately to minimize the total molecular energy. The Illiac will be used to determine these coefficients, to calculate certain molecular integrals, and to perform the matrix operations necessary to arrive at answers comparable with experiments.

1118 Computer. Convolution by Impulse Approximation. The transfer characteristics of a four-pole network can be completely specified by its impulse response. Then, given any arbitrary input function to the network, the output may be found by convolution with the network impulse response. This code accepts the input function and the impulse response as a list or as functions, approximates the functions by trains of impulses, and by a method similar to algebraic multiplication convolves them to form the output response.

1119 Preventive Medicine, University of Utah. A Study of the Psychological Makeup of Medical Students. The research problem is concerned with the measurement and description of medical students in the realm of both personality variables and cognitive functioning for purposes of better selection and training. A factor analysis of 144 variables of data collected on 144 University of Utah medical students will be used to determine the underlying structure, and, if possible, allow formulation of a predictive battery of tests.

1120 T Electrical Engineering. Radiation Patterns of Slot Antennas on Dielectric Coated Spherioids. The problem is to evaluate the effects of dielectric coatings on the radiation patterns of slot antennas on conducting spheroids. By restricting the shapes considered to the family of spheroids, it becomes possible to solve Maxwell's equations in separable coordinate systems. The problem then becomes a more or less straightforward boundary value problem. The solution

proceeds by the expanding of the field quantities in a series of approximate orthogonal functions and determining the value of the coefficients so as to satisfy the boundary condition over the slot and conducting surface.

1121 T Chemistry. The Poisson-Boltzmann Equation. The Poisson-Boltzmann equation arises in chemical electrostatics, and for spherical ions in solution may be expressed as follows:

$$\frac{1}{x^2} \frac{d}{dx} \left(x^2 \frac{d\phi}{dx} \right) = e^{Z_2 \phi} - e^{-Z_1 \phi} - A ,$$

where Z_2 is the charge of the ion, Z_1 that of the surrounding ions, ϕ is the potential (electrostatic) at distance x from the ion and A is a parameter relating to charge density. The solution will involve a parameter x_0, related to the ion radius.

The case where $Z_1 = Z_2 = 1$ has been programmed and solved on the Illiac by Berkowitz (1954). The current problem is to extend the range of Z_1 and Z_2 to cover the values 1, 2, 3, 4 where $Z_1 \neq Z_2$.

The method of solution employs binary chopping in conjunction with the Runge-Kutta iterative method (Library Routine F-1). Binary chopping is necessary due to the fact that the initial conditions involve two slopes, at $x = 0$ and $x = \infty$, rather than a point and slope at $x = 0$.

1122 Physics. Cyclotron Deflector Paths. The paths of ions in a cyclotron deflector channel will be calculated using tabulated values of the magnetic field.

1123. Electrical Engineering. Space Diversity Study in Small Aperature Radio Direction Finders. A method for averaging bearings at several locations is sought which will minimize the errors due to wave interference. These results will also be used to find an optimum number and spacing of antenna arrays which yield an average bearing with least error.

1124 T Physics. Eigenvalues and Eigenvectors of Hamiltonian Matrix. This research is in the general category of solid state physics, specifically a paramagnetic resonance investigation of the electronic structure of cupric

states in silver chloride. The analysis of this problem involves the solution of a particularized form of Schroedinger's equation and may be formulated as a matrix eigenvalue problem. The machine solution for eigenvalues and eigenvectors can be used to compare theory and experiment and also as a guide for choosing basis functions for getting approximate solutions in closed form using standard quantum mechanical perturbation theory.

1125 Bureau of Educational Research. Factor Analysis of Ego-Autonomy Tests. To determine the factors accounting for variance in a battery of tests aimed at the measurement of ego-automony and other psychological variables. Illiac will be used in computing the factor analysis using standard library routines. The outcome of the work will, it is hoped, lead to improved understanding of the ways in which "ego-autonomy"--a general tendency to be self-determining as against environmentally influenced--operates in various areas of opinion, aesthetic preference, reasoning, perception, etc.

Table I shows the distribution of machine time for the month of February.

TABLE I

	Hrs:Min
Regular Maintenance	45:33
Unscheduled Maintenance	11:51
Drum Engineering	74:30
R.A.R.	5:27
Leapfrog	65:11
Wasted	:00
Use by Departments	
Computer	46:26
Physics	5:42
Control Systems Lab.	74:51
Structural Research	34:20
Struct. Res. (AF 24994)	2:07
Psychology	25:23
Electrical Engineering	4:35
Elect. Eng. (AF 3220)	11:52
Elect. Eng. (SC 74898)	:06
Chemistry	22:02
Agriculture	14:04
State Water Survey	3:13
Inst. of Communications Res.	2:58
College of Medicine	4:27
Mech. Eng. (ORD 1980)	:59
Mech. Eng. (CONVAIR)	:43
Jewish Hospital, St. Louis (Institute of Mental Hygiene)	9:27
Demonstrations	:49
Miscellaneous	23:13
	489:49

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 A.M. and 11:00 A.M., and for a check of its performance between 5:30 and 6:30 P.M. of each weekday. Since the periods between 7:00 and 11:00 A.M., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error standpoint to look at the periods between 11:00 A.M. and 7:00 A.M. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between 11:00 A.M. and 7:00 A.M. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. During the 5:30-6:30 period (when the machine is checked) if no errors are found, the time is given to the "running" column. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for February.

TABLE III

Punch Error	2
Control Error	1
Arithmetic Error	4
Memory Error	1
Input-Output Error	1
Drum Failure	10
Power Supply Failure	1
Total	20

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
2/3/58	20:00	:00	0		0	:47	0
2/4/58	20:00	:00	0		0	1:03	0
2/5/58	19:53	:07	1	(1) Drum failure	0	1:24	0
2/6/58	18:30	1:30	2	(1) A and operate signal going to 0(-) Replaced tubes in decoding chassis (2) +100v power supply varying causing leapfrog failure	0	3:23	2
2/7/58	19:30	:30	1	(1) Drum failure	0	4:17	0
2/10/58	19:59	:01	1	(1) Punch No. 4 jammed	0	2:40	0
2/11/58	20:00	:00	0		0	1:10	0
2/12/58	19:18	:42	2	(1) Drum failure (2) Punch No. 4 - A gate bad	0	2:16	0
2/13/58	20:00	:00	0		0	1:11	0
2/14/58	20:00	:00	0		0	1:05	0
2/17/58	20:00	:00	0		0	3:58	0
2/18/58	20:00	:00	0		0	2:27	0
2/19/58	20:00	:00	0		0	4:09	0
2/20/58	15:51	4:09	3	(1) Drum failure (2) Drum failure (3) Drum failure	0	4:26	0
2/21/58	19:35	:25	1	(1) Drum failure	0	3:22	0
2/24/58	20:00	:00	0		0	2:41	0
2/25/58	19:51	:09	4	(1) (2) (3) (4) } Arithmetic errors, due to shorted K-Fil-6BQ7-Adder 2^{-30} pos. V35	0	3:23	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
2/26/58	19:29	:31	1	(1) Input-output failure	0	3:09	0
2/27/58	19:48	:12	3	(1) Drum failure (2) Drum failure (3) Drum failure	0	3:00	0
2/28/58	19:30	:30	1	(1) Memory error Pos. 2^{-37}	0	4:00	1
TOTALS	391:14	8:46	20		0	54:01	3

Reports and Seminars

Report

"A New Class of Digital Division Methods", by James E. Robertson, February 25, 1958.

Seminars

"Some thoughts on Logical Design and Floating Point Arithmetic", by Dr. Nicholas Metropolis, University of Chicago, February 11, 1958.

"The Application of Change Chart Theory to Control Design Problems", by James Shelly, February 18, 1958.

"The Flow-Gating Flipflop", by Sylvian Ray and Neil Wiseman, February 25, 1958.

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Physics

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

1958

PART I - HIGH-SPEED COMPUTER PROGRAM

PART II - MATHEMATICAL METHODS

PART III - ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

March, 1958

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part through Contract No. AT(11-1)-415 of the Atomic Energy Commission. The contract is supported jointly by the Atomic Energy Commission and the Office of Naval Research. In addition, this work is supported through Contracts N6ori-07130 and Nonr-1834(15), both from the Office of Naval Research.

The University of Toronto is participating in this work through staff members of its Computation Centre.

1. Transistor Circuits

The problem of high-powered drivers has now found a more or less satisfactory solution. The final design (see Figure 1) differs considerably from what was thought to be an optimum design (see January, 1958, monthly progress report), one of the reasons for the difference being the strong β decrease reported on in February. Furthermore, low collector voltages slow down the operation to such a degree that the idea of running the transistors at a collector-to-base voltage of 1 or 2 volts had to be abandoned. Another difficulty encountered was the paralleling of emitters in the emitter-follower part of the push-pull circuit. For load impedances of less than 100 Ω the stabilizing resistors in series with each emitter have values in the neighborhood of the variation of H_{11} from one unit to the next. Timing troubles between the two sections of the push-pull output were also hard to overcome.

In view of these difficulties a scheme was developed in which all output transistors are tied together on the collector side, the emitter being driven with a practically constant current which is switched between it and a diode returned to 6v. The load is connected between the common collector point and ground, and this point is tied to a collector supply voltage of -3v through a 20Ω resistor. Two diodes bump the output to +2v and -2v. The idea behind this system is that, for all capacitive loads ordinarily encountered, the time constant in the negative-going direction is no longer than that in the positive-going direction because of the extremely small equivalent impedance ($< 20\,\Omega$) in the collectors.

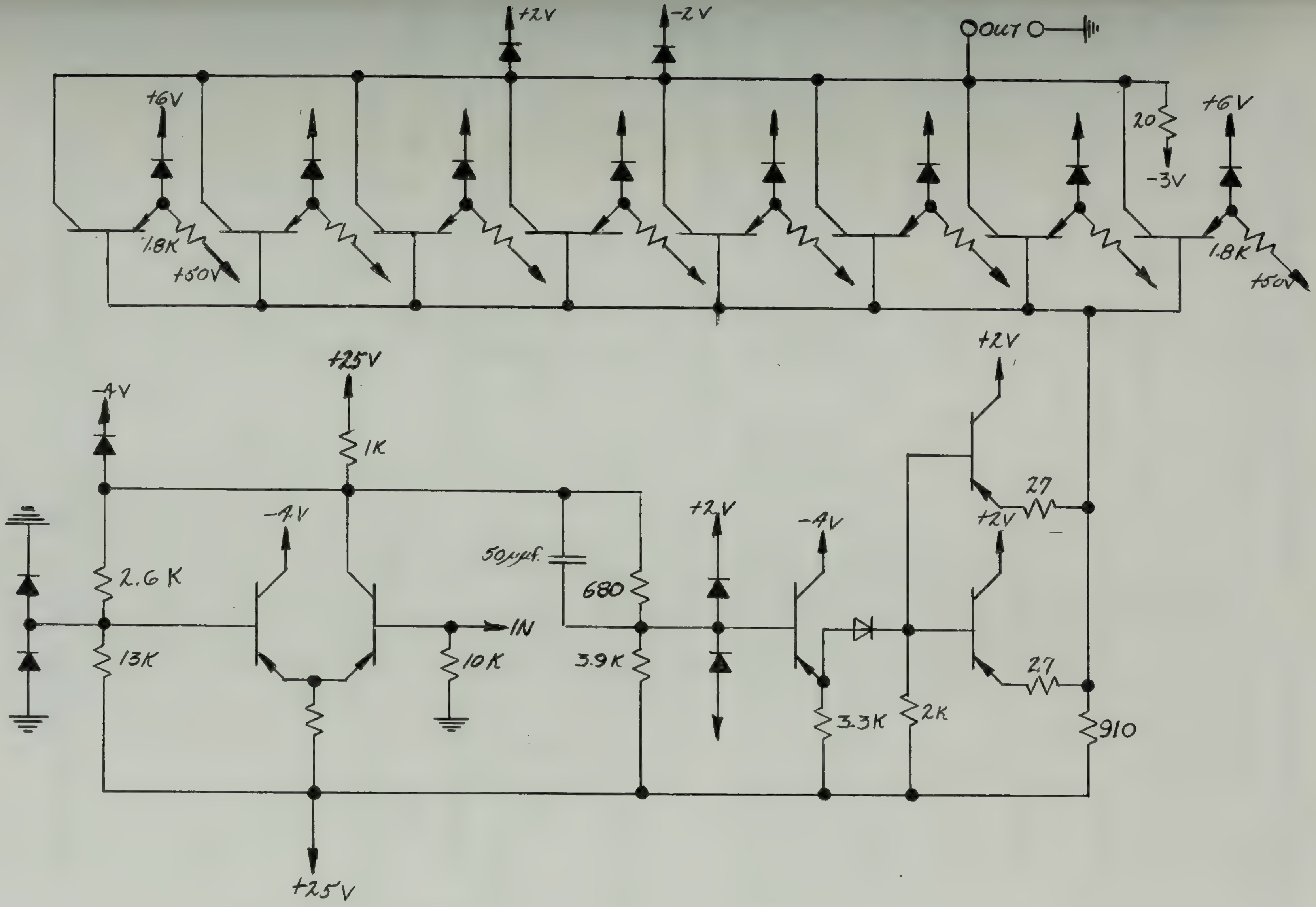


Figure 1
200ma DRIVER
Rise and Fall Times < 20mμs with 100μμf to Ground

The rest of the circuit in Figure 1 is essentially a Schmitt trigger, modified to accept very small trigger signals. The two diodes (both being returned to ground) to the left limit the swing of the left-hand base to about ± 0.4v. The purpose of this is to be able to use very degenerated (even sine-wave) signals at the input. The output swing of the Schmitt trigger is bumped and goes into an emitter-follower; this emitter-follower has its output stepped down to the switching range of the last power stage by a 6v Zener diode. The operation time of this circuit is not yet available, but both rise time and fall time (with either 100 μμf at the output or twenty diode ANDs in parallel) is less than 20 mμs. A special advantage of the circuit is its great stability due to the lack of feedback. This has as a consequence a very clean wave form. Currents of up to 200ma can be furnished.

(N. Johnson)

Another positive result was obtained with the emitter-base crosscoupled flipflop described last month. A minor change was introduced in order to obtain a fan-out of 2 for the design. Gating is no longer obtained by diodes going into the collectors of the center transistors (see Figure 2), but by Zener diodes going into the bases of these transistors.

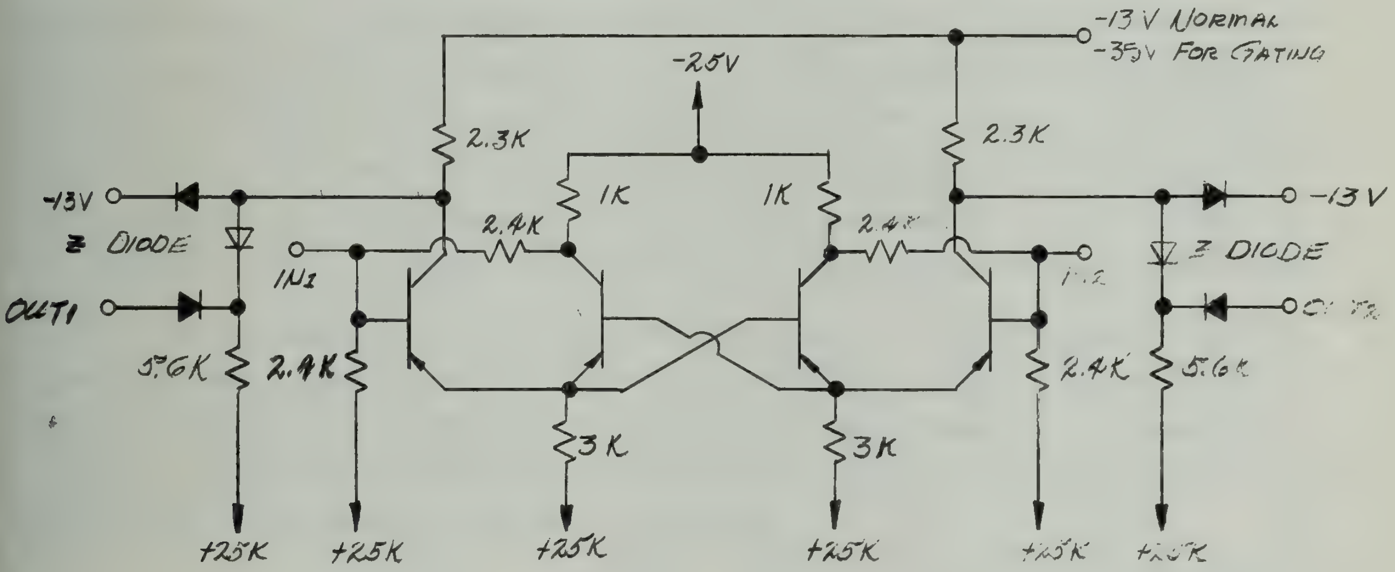


Figure 2
EMITTER-BASE CROSSCOUPLED FLIPFLOP WITH ZENER DIODE GATES

The circuit shown was first optimized by (graphical) relaxation methods and then subjected to a complete tolerance analysis on Illiac. As shown, the resistor tolerance is ± 3%, the voltage tolerance is ± 3% and any alpha between .95 and 1.00 is acceptable. These requirements are about the same as those for the standard Eccles-Jordan flipflop developed by this Laboratory. The interesting thing is that last-moving points (in phase with the corresponding inputs) are obtained without additional circuitry. The operation time of the new flipflop is less than 18mμs as compared to more than 27mμs for the Eccles-Jordan type. Work is now in progress to build gate drivers in the form of a single transistor, to be incorporated in each unit.

(N. Wiseman and S. Ray)

2. Core Memory

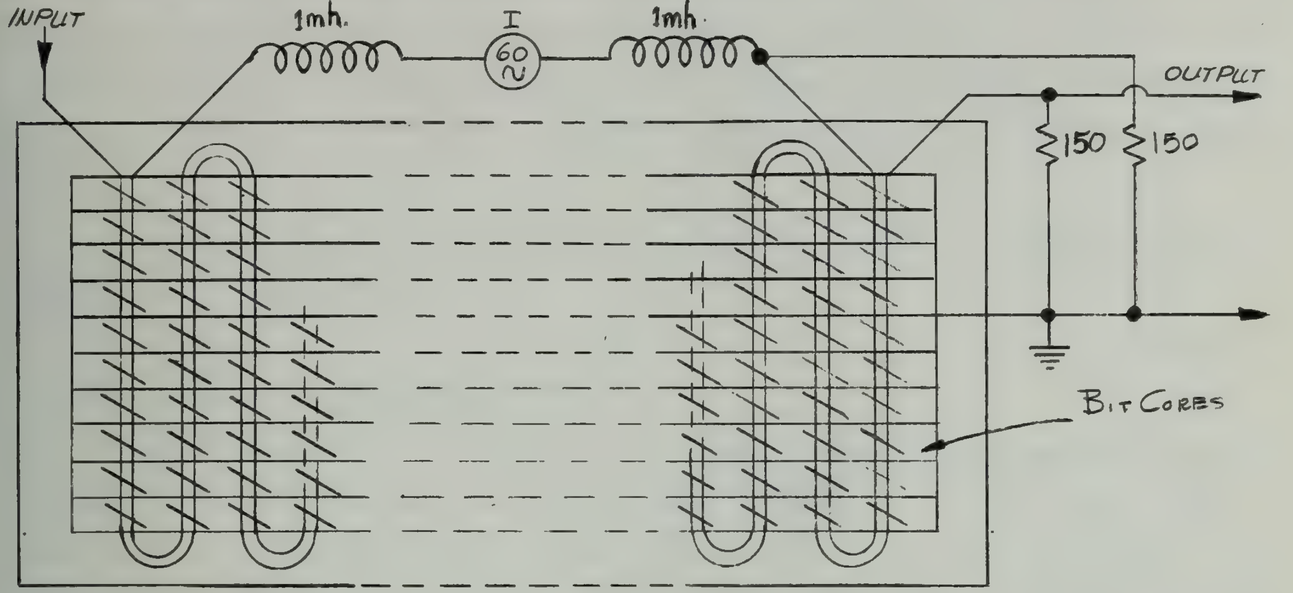
Read Amplifier Design. The core read amplifier design for signals in the 200mv region was completed. The worst case calculations indicate that a signal to noise ratio of 7:1 or better would always be satisfactory. The amplifier actually is built with a flipflop and strobe circuitry on the same chassis. A total of 10 transistors and 2 Zener diodes are used which include the output emitter-followers for complementary outputs. If a signal to noise ratio as high as 8:1 can be obtained, the design can very easily be changed, by changing two resistors, to handle minimum signals from 135mv to 400mv. The overload characteristics seem to be satisfactory for short overload pulses. A larger capacitor may be required in the feedback loop for overloads as long as 1μs. The delay in the amplifier proper is 50mμs. The strobe logic adds approximately another 30mμs.

An experimental gate driver was built using a feedback approach and a pullup-pulldown output stage. A 60mv output circuit was used. A total delay of 20mμs was obtained for the positive direction and about 25mμs for the negative direction. Some high frequency oscillations were encountered in the feedback loop, however, and these have not yet been eliminated.

(G. Leichner)

Delay Studies. A study has been undertaken in the period of this report covering the delay associated with the sense and rewrite windings of memory ferrite core planes. The tests were designed to determine the possibility of regarding these windings as transmission lines, and, if so, what the termination resistance

would be. Also, the delays associated with various types of 50 mil bit cores were to be determined. It was assumed for the purposes of this test that the memory could be simplified to the configuration shown below:



One thousand cores of a given type were threaded on two wires and laid out on a board in the configuration shown. Grounded cross wires were added to simulate the associated capacities of the word drive lines, and to separate the cores from each other. A pulse was made by feeding the output of a switched 50 mil core of similar material into the sense winding and observing the pulse as it emerged at the other end of the array. One plane was wired without cores to observe the delay associated with the wire itself. A low frequency AC current was run through the rewrite line (through chokes) to observe the variation in delay associated with the cores in various states of saturation.

It was found that the sense and rewrite windings could indeed be regarded as a transmission line with a termination impedance of approximately 150 ohms, regardless of the type cores used. The delay characteristics of the core types used are tabulated below:

	I	Delay in mμs/1000 cores	
Core Type	ma	Unsaturated	Saturated
wire alone	--	20	20
50T1	550	27	25
RCA 3673	250	30	26

In each case, the length of wire was 18.2 feet. It can easily be seen, then, that the chief contribution to delay in the sense and rewrite lines is due to the length of wire involved--the core effects are definitely secondary. The change in delay associated with the state of the cores is perhaps significant with respect to the core delay, itself, but considering the total delay, it seems that the change in delay associated with core states can never amount to more than 10% of the total delay.

A similar test is being made of the various types of cores suitable as switch cores for the memory.

(C. Pottle)

3. Input-Output and Auxiliary Storage

More information was received on commercially available magnetic tape equipment and other input-output devices; new information is summarized below. A large amount of time during this month was devoted to learning something about transistors and transistor circuits, especially as applicable to magnetic recording circuits.

Paper Tape Equipment. New literature received from Soroban describes their new GP-2 paper tape punch, capable of punching up to 240 characters/second in any of several codes (up to 8 holes on standard tape widths).

Potter Instrument Company has announced that their model 906 magnetic tape handler can be supplied with a replaceable capstan panel, which converts the unit to a paper tape handler. The company's claim is that 1,000 characters/second can be read, and that the tape can be stopped on the stop character. Potter also has a model 903 paper tape reader available in the 150, 300, and 600 characters/second speeds. The 600 characters/second machine requires one extra character space to stop.

Magnetic Tape Units. It appears that Potter and Ampex have the field all to themselves for digital magnetic tape handling. Theirs appear to be the only high-speed tape transports capable of fast start-stop operation--that is, start-stop time of 5 ms or less.

	Potter 906	Ampex FR 300
max. record and playback speed	150 ips	150 ips
multiple speeds?	yes	no
tape width	≤ 1.25"	1" or 1/2" only
max. channels	47	16
start time	3ms	1.5ms
stop time	1.5ms	1.5ms
rewind speed	400 ips	full 2500' reel in 2.25 min. (avg. of 200 ips)
search speed	400 ips	none specified
max. recommended start-stop cycle rate	200 cps	not specified 300 cips or less
start-stop mechanism life (no. of operations)	100,000,000	50,000,000

Minneapolis Honeywell tape transports do not appear to be suitable because of very long start-stop times--seconds rather than milliseconds. However, there is a Honeywell installation at Radiation, Inc. (Florida) which operates with packing densities of 400 bits/inch. This is the highest figure that has been mentioned in any commercial system to date. Under ideal laboratory conditions, Honeywell has achieved successful record-playback up to 1200 bits/inch. One head manufacturer enclosed a figure showing approximately sine-wave playback; the claim was made that pulse densities of 2000/inch were used.

Circuits. The objective of current circuit development activities is to develop transistorized "write" circuits for magnetic tape recorders. Two such circuits have been designed by T. Murrell and fabricated in the shop. Testing of the first has just begun.

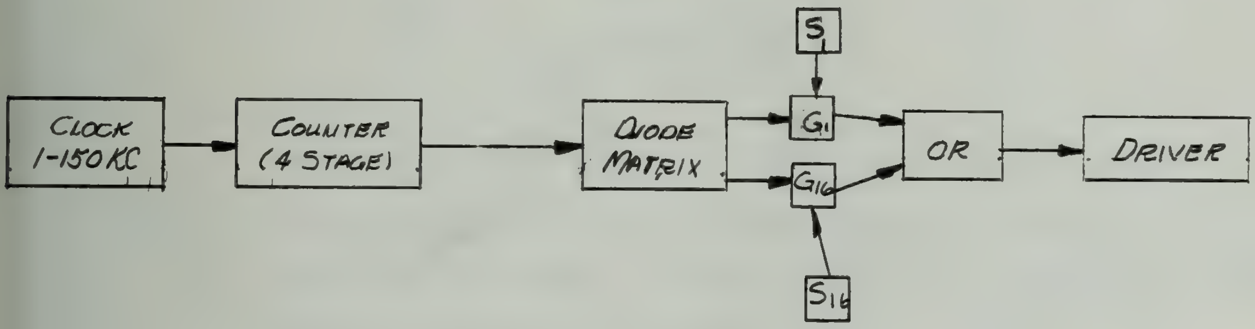
In order to test driving circuits under simulated operating conditions, it will be necessary to arrange for an arbitrary series of pulses to be impressed upon the recording head. The following block diagram represents a system which will cycle through a series of 16 pulse positions, each of which may be set to represent a "1" or a "0". The pulse repetition rate may be varied from less than 1000 pps to over 150,000 pps.

The "clock" has been built and tested; it consists of a transistor multivibrator, free-running, with six overlapping speed ranges and continuous speed control within each range. This construction was chosen mainly to assist in familiarizing the writer with transistor multivibrator circuits.

The counter, diode matrix, and OR circuits shown in the block diagram are still in the design stage. Until these circuits are completed, driving circuits under test are being driven directly by (approximately) square waves generated by the multivibrator. The test pulse train is thus limited to alternate 1's and 0's.

Driver circuits are being tested with a dummy head, consisting of a choke of approximately 150Ω d.c. resistance and 10 mh inductance. This is a reasonable approximation to some head characteristics, except that it has no center tap.

Some of the blocks in the diagram may be useful when the time comes for acquiring reliability data on tape recording and playback.



(R. Cummins)

PART II

MATHEMATICAL METHODS

1. Iterative Methods for Solving Systems of Linear Equations

(Supported in part by the Office of Naval Research under Contract N6ori-07130)

A study is being made of the iterative procedure (cf. November, 1957, and February, 1958, monthly reports)

$$x_{i+1} = Gx_i + Hy$$

where the matrix G is related to the matrix A of the system, $A_1x = y$, as follows: The matrix A_1 is reduced to the form

$$A = D^{-1/2}A,D^{+1/2} = I + L + U$$

where D is the diagonal matrix consisting of the elements on the main diagonal of A_1 and I is the unit matrix,

$$\begin{aligned} L &= a_{ij} && i > j \\ &= 0 && \text{otherwise} \end{aligned}$$

$$\begin{aligned} U &= a_{ij} && j > i \\ &= 0 && \text{otherwise} \quad . \end{aligned}$$

Then,

$$G = (I + \omega U)^{-1} \left[(1 - \omega)I - \omega L\right](1 + \omega L)^{-1}\left[(1 - \omega) - \omega U\right].$$

This definition of G corresponds to using an over relaxation technique on a two-step process in which the approximant to the solution of the equations is first manipulated in one order and then in the reverse order. Thus, let

$$Z_i = x_i + \omega \left\{y - LZ_i - Ux_i - x_i\right\}$$

then Z_i

$$x_{i+1} = Z_i + \omega \left\{y - LZ_i - Ux_{i+1} - Z_i\right\} \quad .$$

If the values of Z_i from the first equation are substituted into the second, an expression is obtained for x_{i+1} in terms of x_i of the form given above with the G indicated.

Now, if the eigenvalues of G are less than one, then the iterative scheme will converge. For A positive definite and symmetric, then it can be shown that the eigenvalues are less than one for $0 < \omega < 2$. Furthermore, the operator can be shown to be similar to an operator which is symmetric and positive definite. Thus, for all $0 < \omega < 2$, the operator has real simple elementary divisors which are less than one and positive. The question of how to choose ω such that the maximum eigenvalue is minimized is being investigated.

(G. Golub)

2. Einstein-Maxwell Field Equations (Supported in part by the National Science Foundation under Grant G2794.)

A report on the problem and results described in the February, 1958, monthly report has been written.

An investigation is being undertaken of plane-symmetric space times in which there exists a plane-symmetric solution of the Maxwell equations with no current present. The aim is to determine whether Birkhoff's theorem on the non-existence of truly time dependent solutions in the spherically symmetric case holds in the plane-symmetric case.

(S. Patnaik)

3. Hydrodynamic Flows with Shocks (Supported in part by the National Science Foundation under Grant G2794.)

The formulas for integrating the equations describing the propagation of a uniform shock in a one-dimensional flow lead to a set of quantities ρ_k^n approximating the density at $x = k\Delta x$, $t = n\Delta t$. These are usually monotonic in k for fixed n. By regarding ρ_k^n as a distribution function, we may define the "mean" μ_n and the "variance" σ_n^2 by the equations

$$\mu_n = \frac{1}{\rho(2) - \rho(1)} \sum_{k=-n}^{n} (\rho_{k+1}^n - \rho_k^n)\, k\Delta x$$

$$\sigma_n^2 = \frac{1}{\rho(2) - \rho(1)} \sum_{k=-n}^{n} (\rho_{k+1}^n - \rho_k^n)\, (k\Delta x - \mu_n)^2$$

where $\rho_{(2)}$ and $\rho_{(1)}$ are the two "constant" levels between which ρ_k^n varies monotonically in the interval $-n \leq k \leq n$.

In some integration techniques it can be shown that

$$\mu_n = n v \Delta t$$

where v is the theoretically correct shock velocity and

$$\sigma_n^2 = n v \Delta t(\Delta x - v \Delta t).$$

Integration schemes which lead to smaller values of σ_n^2 are being sought.

(C. Farrington)

PART III

ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

Machine Use

During March, specifications were presented for 11 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1126.

1126 T Chemistry. Nuclear Electric Quadrupole Interaction. The problem involves an investigation of how the nuclear electric quadrupole moment interacts with the crystalline electric field gradients present in ionic crystals having non-cubic symmetry. $NaBrO_3$, $NaClO_3$, and $NaNO_3$ are to be studied. It is found that the energy of this interaction as a function of volume does not follow the simple theoretical picture previously assumed to be true. An explanation of the experimental anomalies will be sought on a basis of anisotropic changes of atomic positions in the unit cell as a function of volume. The field gradients function as a function of several variables will be summed over the nearest neighbors to a given atom in the unit cell. This function has the form:

$$eq = \frac{3Z^2}{(Z^2 + a^2)^{5/2}} - \frac{1}{(Z^2 + a^2)^{3/2}}$$

and will be summed over nearest neighbor atoms

$$\left(\frac{\partial^2 V}{\partial Z^2}\right)_{tot} = \sum_i^n (eq)_i \qquad \text{for n nearest neighbors .}$$

The resulting family of curves will be used to fit the experimental numbers to a specific model of anisotropic change of positions of atoms in the unit cell.

1127 T Dairy Science. Estimation of Variance Components for Body Measurements of of Dairy Cattle. The problem concerns the estimation of components of variance

and covariance as a part of an analysis involving certain body measurement data from dairy cattle.

1128 Bureau of Educational Research. Psychometric Research. An investigation will be made of the possibility of applying various statistical and mathematical techniques to psychometric research.

1129 Physics. Computation of Wavelengths by Hartmann Formula. This program is to be used to calculate wavelengths from spectroscopic observations.

1130 Computer. Mathematics 457 Assignments. The problem consists of integrating two ordinary differential equations using Milne's method and Runge-Kutta.* The purpose of the calculation is to promote a better understanding of the merits of the two methods and to impress upon the student the dangers involved in using approximate methods.

1131 Psychology. Interpersonal Perception in the Assessment of Personality. An investigation is to be made relating perceptual space, i.e., interpersonal perception of significant other persons, to a variety of behaviors which are objectively identifiable. Thus, comparison will be made of delinquent and non-delinquent boys and girls in terms of their perceptions of self, father, mother, teachers, etc.; highly anxious and non-anxious subjects; those who have and those who do not have probably psychosomatic involvement.

1132 University of Iowa (Psychology). Empirical Study of Sampling Fluctuations. The proposed study has two specific purposes:

1. to investigate the stability of factor analysis results by comparing the maximum likelihood solutions of data for two independent random samples from the same population.
2. to contrast the maximum likelihood solution with those of the more widely-known centroid solutions as to the number of factors and the similarity of the factor loadings after rotation.

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* Both problems were assigned by Professor Taub in Mathematic 457.

1133 Civil Engineering. Flat Truss Roof System Design. This problem is basically a refinement of a portion of problem 1038 T. Problem 1038 T undertook the development of least-weight proportions for a large trussed roof system involving several kinds of trusses and certain general assumptions as to load distribution on the trusses. The proposed problem will study the proportions of a roof system made up of only one type of truss, but will give considerably greater emphasis to the design of truss details than did 1038 T. Instead of relating the truss proportions to generalized member cross-sections, actual physical data pertaining to available structural shapes will be stored in the memory in the form of a table and used selectively in the design computations. The same iterative form of stress analysis will be employed in this problem as in 1038 T, since it was found that the Illiac performed quite efficiently in this respect. The problem will test the feasibility of detailed design, for relatively complex structures, by the computer.

1134 Computer. Library Print Subroutine Study. A routine to print fractions at maximum speed is to be written for the Illiac library.

1135 T Structural Research. Behavior of Arches Under Dynamic Loads. Natural frequencies, buckling loads and the corresponding modes are to be calculated for arches which have been approximated by a structure with a finite number of degrees of freedom.

1136 Mechanical Engineering. Thermodynamic Properties of Combustion Products. The concentration of species in the products of various hydrocarbon air mixtures will be determined by successive approximations from 4 linear and 8 non-linear equations, and the thermodynamic properties will be calculated.

Table I shows the distribution of machine time for the month of March.

TABLE I

	Hrs:Min
Regular Maintenance	41:23
Unscheduled Maintenance	10:54
Drum Engineering	51:50
R.A.R.	4:04
Leapfrog	42:28
Wasted	:00
Use by Departments	
Computer	16:56
Physics	19:26
Control Systems Lab.	93:42
Structural Research	42:26
Struct. Res. (AF 24994)	12:42
Struct. Res. (AF 464)	10:16
Psychology	26:30
Electrical Engineering	4:21
Elect. Eng. (Boeing Aircraft)	:37
Elect. Eng. (SC 74898)	1:30
Chemistry	23:30
Agriculture	11:14
State Water Survey	2:55
Inst. of Communications Res.	2:42
Inst. of Com. Res. (PH 9067C)	1:44
Mech. Eng. (ORD 1980)	:14
Mech. Eng. (ORD 593 IC)	2:54
U. of Utah (Psychology)	4:58
U. of Iowa (Public Health)	2:55
Classes	9:24
Demonstrations	22:47
Miscellaneous	22:01
	486:23

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7 a.m. and 11 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 11 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive, from an error standpoint, to look at the periods between 11 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between 11 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. During the 5:30-6:30 period (when the machine is checked) if no errors are found, the time is given to the "running" column. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for March.

TABLE III

Memory	1
Reader	2
Punch	1
Control	1
Drum	10
Unknown	1
Total	16

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
3/3/58	19:45	:15	1	(1) Solder found between pins 6-7 v 53 memory control	0	4:02	1
3/4/58	20:00	:00	0		0	3:42	0
3/5/58	19:56	:04	2	(1) Drum Failure (2) Unknown origin	0	2:08	0
3/6/58	20:00	:00	0		0	2:28	0
3/7/58	18:01	1:59	2	(1) Failure to playback properly from drum (2) Drum failure	0	1:34	0
3/10/58	19:59	:01	1	(1) Drum failure	0	:38	0
3/11/58	20:00	:00	0		0	:54	0
3/12/58	19:46	:14	1	(1) Drum failure	0	:39	0
3/13/58	19:57	:03	2	(1) Reader "k" failed (2) Reader "k" failed	0	1:00	0
3/14/58	19:20	:40	1	(1) Drum failure	0	1:10	0
3/17/58	20:00	:00	0		0	:39	0
3/18/58	19:33	:27	1	(1) Memory failure position 2^{-38}	0	1:10	1
3/19/58	19:35	:25	2	(1) Drum failure (2) Drum failure	0	:58	0
3/20/58	19:25	:35	1	(1) Drum failure	0	:59	0
3/21/58	19:45	:15	2	(1) Punch #3 failing to punch "8" hole (2) Drum failure	0	1:23	0
3/24/58	20:00	:00	0		0	2:25	0
3/25/58	20:00	:00	0		0	3:10	0
3/26/58	20:00	:00	0		0	1:30	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
3/27/58	16:56	:00	0	Illiac turned off at 5:00 a.m. to install new input-output rack	0	:38	0
3/28/58				Illiac not running; installing new input-output rack			
3/31/58	20:00	:00	0		0	:59	0
TOTALS	391:58	4:58	16		0	32:06	2

Reports and Seminars

Seminars

"A New Class of Digital Division Methods", by Prof. James E. Robertson, March 4, 1958.

"Circuit Analysis-Using Computers", by John L. Muerle, March 11, 1958.

"A Statistical Approach to the Tolerance Problem of Circuit Design", by Gene Leichner, March 18, 1958.

"Numerical Stability of Certain Integration Formulas in Hydrodynamics", by Carl C. Farrington, March 25, 1958.

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Physics

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM

PART II - MATHEMATICAL METHODS

PART III - SWITCHING THEORY

PART IV - ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

April, 1958

PART I

HIGH-SPEED COMPUTER PROGRAM

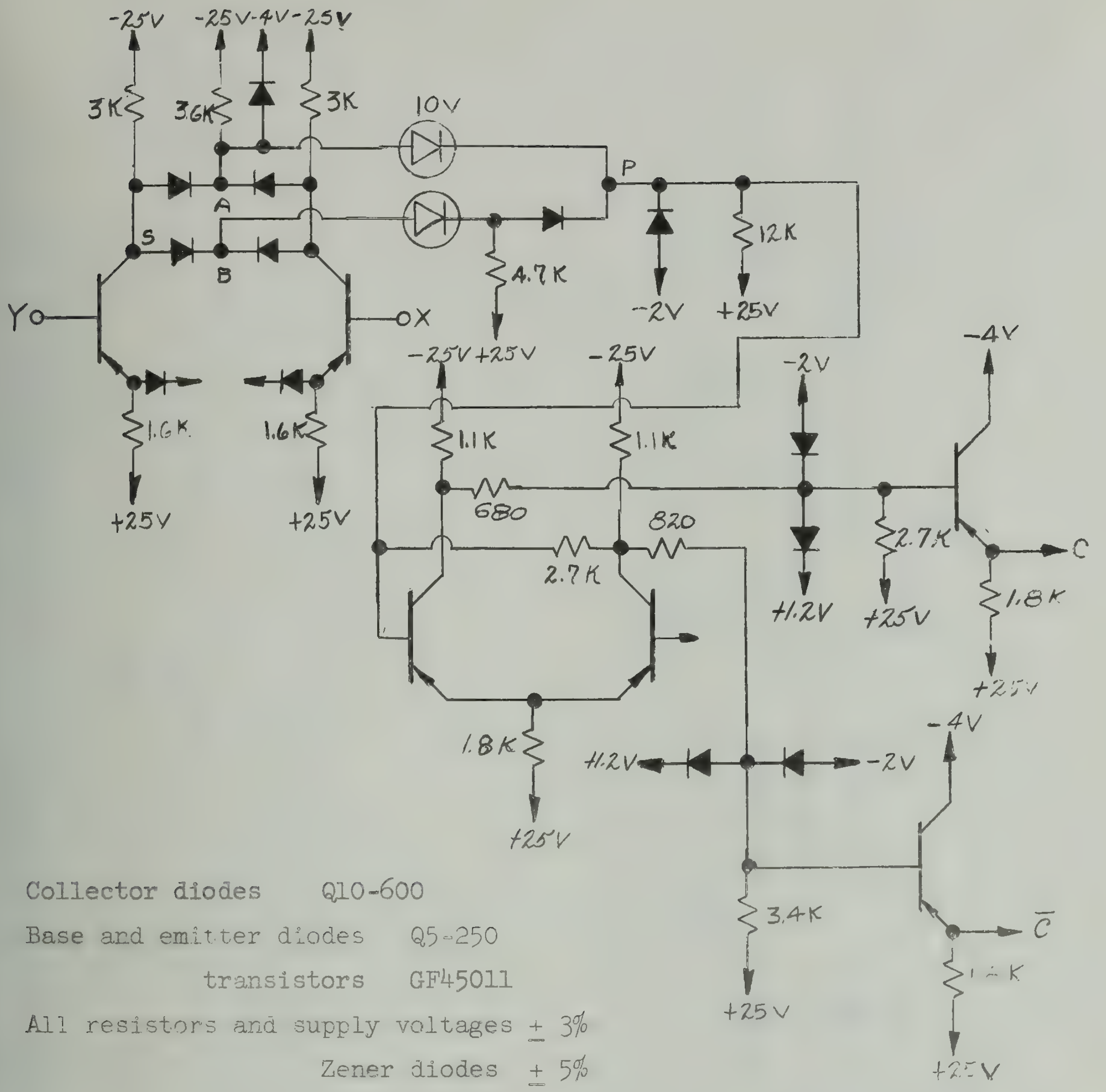
This work is supported in part through Contract No. AT(11-1)-415 of the Atomic Energy Commission. The contract is supported jointly by the Atomic Energy Commission and the Office of Naval Research. In addition, this work is supported through Contracts N6ori-07130 and Nonr-1834(15), both from the Office of Naval Research.

The University of Toronto is participating in this work through staff members of its Computation Centre.

1. Transistor Circuits

The investigation of the emitter-base crosscoupled flipflop with flow-gating was continued throughout the month. Several alterations of the basic circuit shown in last month's progress report were considered. Approximate designs were calculated by hand, and the computer was used in a three-to-four step improvement process. From the considerable amount of data, it was determined that the alpha requirements for the flipflop were much higher than anticipated. As for the standard flow-gating flipflop one must have alpha $\geq .98$. Under these circumstances flow-gating for this type of flipflop was abandoned, especially since for double-gating its advantages are minor.

A new C or $\bar{C}$ element was developed. This is a storage element with two inputs. If the inputs are different, the last state is retained; if they coincide, the output follows the input in the case of the C element, or gives the complement in the case of the $\bar{C}$ element. Many circuits can be designed which have this property (see July, 1956, Progress Report), but the tolerance conditions are usually hard to satisfy. Figure 1 gives the layout of the new design which is essentially a Schmitt trigger preceded by two switching inverters having diode ANDs and ORs between the collectors. The output of the AND and OR feed the input of the Schmitt trigger through two Zener diodes, their voltage difference providing the necessary hysteresis. Tolerance calculations show that the new circuit is easy to design for worst case conditions. Preliminary tests gave operation times of the order of 30 mμs for either one of the outputs. It should be remarked that the C output is not truly a last moving point.



Collector diodes Q10-600

Base and emitter diodes Q5-250

transistors GF45011

All resistors and supply voltages ± 3%

Zener diodes ± 5%

Figure 1

C or C̄ ELEMENT

A plug-in package was designed for the driver circuit discussed in last month's progress report. Some circuit modifications were made in order to comply with the standard supply voltages. Figure 2 shows the redesigned circuit, and Figure 3 gives typical waveforms obtained with a logical oscillator using the output of the driver to provide the reply-back signal. More speed could be obtained by using a free-running logical oscillator.

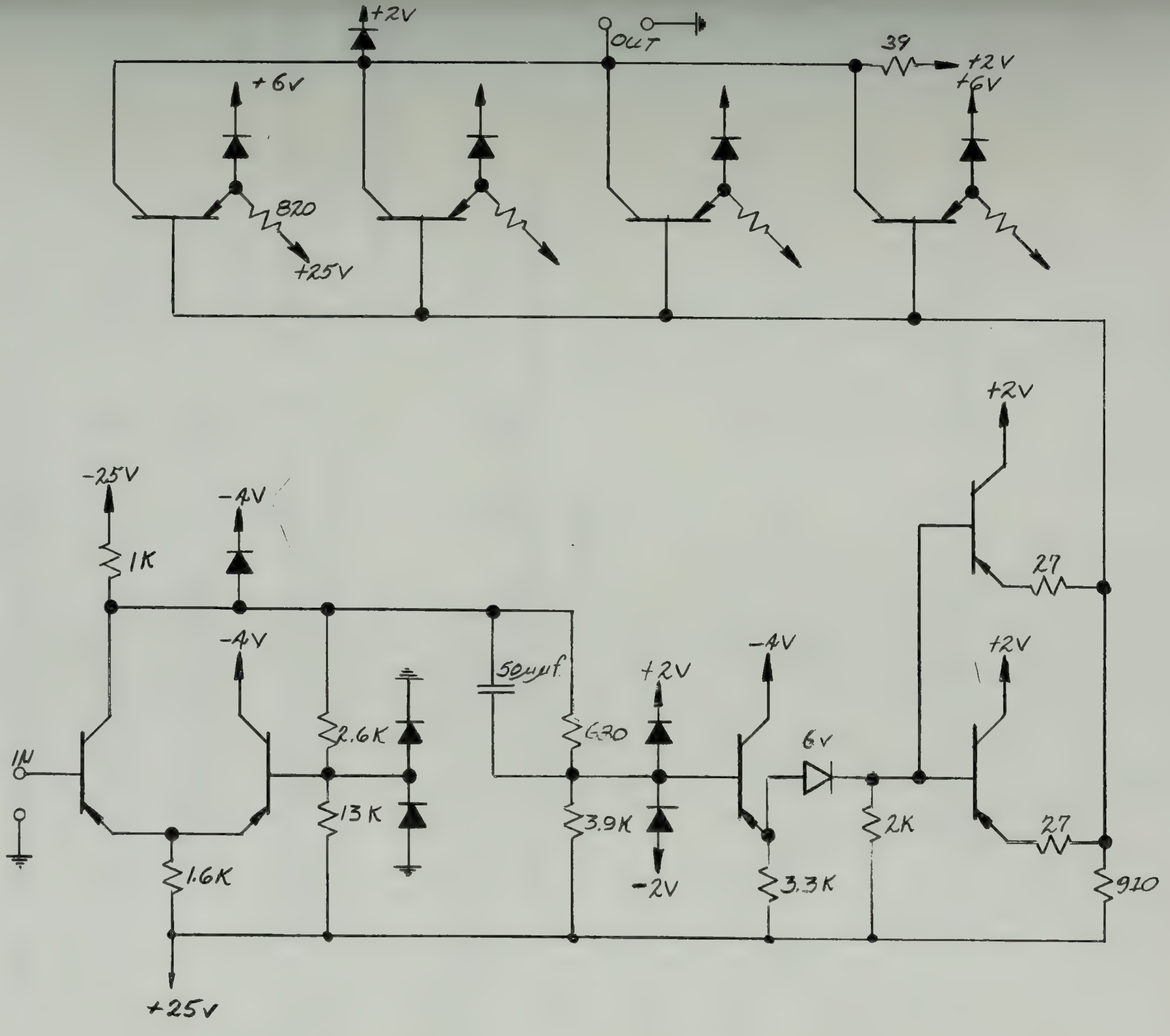


Figure 2

PLUG-IN DRIVER CIRCUIT

(100 ma, Rise Time $<$ 20 mμs)

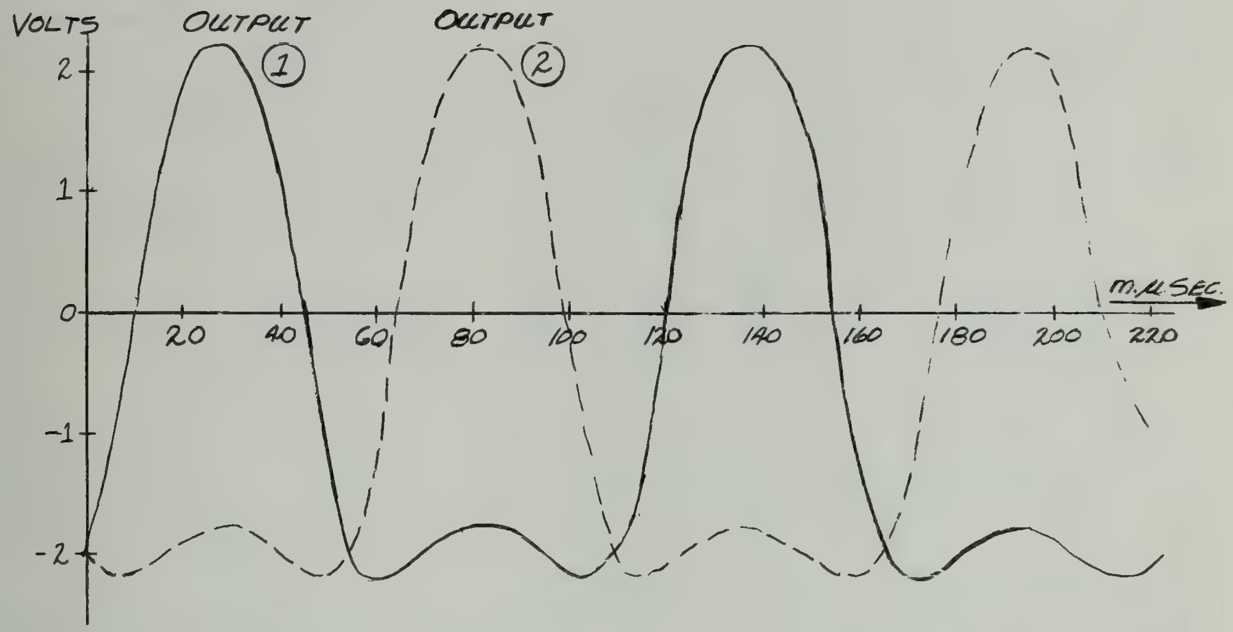


Figure 3

APPROXIMATE WAVEFORMS OF OUTPUTS OF LOGICAL OSCILLATOR USING PLUG-IN DRIVERS

(N. Wiseman, S. Ray, N. Johnson and J. Muerle)

2. Arithmetic Unit

A proof was devised confirming several features of the multiplier recoding described in Report No. 80. Using the following notation for the kth step of a binary multiplication,

w_{n-k+1}	mode digit sensed during kth step
w_{n-k}	new mode digit resulting from kth step
y_{n-k}	least significant of multiplier digits sensed during kth step

z_{n-k} recoded multiplier digit (each $z_i = -1, 0,$ or $+1$),

it can be shown that

$$z_{n-k} = y_{n-k} + w_{n-k+1} - 2w_{n-k} .$$

The recoded multiplier y, after n+1 steps, is then

$$y = \sum_{i=0}^{n} 2^{-i} z_i = \sum_{i=0}^{n} 2^{-i} y_i + \sum_{i=1}^{n+1} 2^{-i+1} w_i - \sum_{i=0}^{n} 2^{-i+1} w_i$$

$$= y_0 + \sum_{i=1}^{n} 2^{-i} y_i + 2^{-n} w_{n+1} - 2w_0 .$$

For a two's complement representation of y,

$$y = -y_0 + \sum_{i=1}^{n} 2^{-i} y_i , \text{ implying that } w_{n+1} = 0 \text{ and } w_0 = y_0 .$$

For one's complement, $y = -y_0(1-2^{-n}) + \sum_{i=1}^{n} 2^{-i} y_i$,

implying that $w_0 = w_{n+1} = y_0$.

It should be noted that $w_0 = y_0$ can be accomplished by setting $y_{-1} = y_0$

(J. Robertson)

Calculation of Carry Chain Lengths. A Monte-Carlo program for determing lengths of carry-carry completion chains was run. Results are summarized in the table below, in which the average chain length c is given as a function of the number of digital positions n. 4096 points were used to calculate each entry in the table.

n	c	n	c
40	4.69	52	5.06
41	4.74	53	5.09
42	4.74	54	5.17
43	4.75	55	5.14
44	4.75	56	5.15
45	4.84	57	5.25
46	4.88	58	5.16
47	4.95	59	5.24
48	4.89	60	5.28
49	4.95	61	5.29
50	5.00	62	5.34
51	5.04	63	5.35
		64	5.38

The construction of the Monte Carlo program lead to the realization that certain operations are really nothing more than Boolean-homomorphisms of the Boolean algebra which the various digit combinations give rise to. Examples are:

a. Logical right and left shifts of A, circular shifts of A (maps 53 digits of A onto the 53 digits of A).

b. Logical right and left shifts of AQ (maps 106 digits).

c. When x is a double length number in A, Q, taking most and least significant parts of x, m(x), L(x), which maps AQ onto an algebra of 53 digits. Note that

$$m(x \vee y) = m(x) \vee m(y) \qquad L(x \vee y) = L(x) \vee L(y)$$
$$m(\bar{x}) = \overline{m(x)} \text{ , etc.}$$

These considerations lead to a formal characterization of addition and subtraction by functional equations:

$$\text{Addition: } a \text{ x } b = (a + b) \text{ x } \varphi(ab)$$
$$\text{Subtraction: } a \text{ o } b = (a + b) \text{ o } \varphi(\bar{a}b) \text{ .}$$

These relations have been completely analyzed.

(R. Farrell)

3. Control Studies

Floating Point Arithmetic. It is proposed that a floating point number in the core memory should consist of a 45-bit fractional part and an 8-bit base 4 exponent. This is equivalent to a range of about $10^{\pm 77}$, and a minimum precision, for standardized numbers, of one part in 4×10^{12}.

Non-standardized multiplication may be performed by first comparing the two fractional parts, standardizing the one of larger absolute value, and noting whether its absolute value then lies in the range 1/4 to 1/2. The unrounded product of the two fractional parts (one standardized) is formed, and if the magnitude of the standardized factor was between 1/4 and 1/2, the product is shifted left one place (multiplied by 4), provided this does not cause overflow. This means, in effect, that the less significant number is multiplied by a number between 1/2 and 2 in magnitude, and the result scaled only if overflow occurs.

For a base 4 computer, this minimizes the maximum change in significance (one binary place left or right), but does not have the property that the expected value of the fractional part of the product equals that of the smaller of the fractional parts of the factors. If non-zero standardized fractions are assumed to be distributed as $1/x$ (the unique continuous density invariant under multiplication by an arbitrary non-zero factor and change of base), then the expected absolute value of the product is about 8% higher than the smaller factor. Other assumed distributions give 10% or 15% increase. It is felt that if significance changes during multiplication, it is better for it to increase than decrease.

Data on the inversion of a 6 x 6 Hilbert matrix by non-standardizing floating point was obtained and sent to Professor Metropolis. This appears to be a case in which the non-standardizing arithmetic is not appropriate for the back substitution since rounding errors are not independent.

(R. Farrell and D. Gillies)

Trial Programming

Eight sets of ordinary differential equations, which arose at MURA, were studied as examples of miscellaneous algebra. They were sufficiently complex and different that they probably provide a fair test for this type of problem for the

proposed computer. Exclusive of functional subroutines, the time for arithmetic was between one and two times the memory time, and the majority took nearly twice as long for arithmetic. Except for a short delay of the arithmetic unit at the start of most functional subroutines, overlap of memory time with arithmetic time was very nearly perfect. The reasons for the surprisingly small use of the core memory appear to be

1. the high frequency of such operations as squaring, which require only one memory reference per multiplication,
2. the high density of multiplications and divisions,
3. the large number of temporary results which can be held in fast registers rather than stored in the main memory
4. the fact that nearly all instructions can be made short by holding addresses in B-lines, and
5. the absence of arithmetic-conditional jump instructions.

(W. Gear)

Over-all Design. From considerations of the duty cycle of the core memory, it is felt that if sufficiently cheap slow circuitry can be built, the input-output control should be able autonomously to transfer blocks of data between the drum and core memory and between any two selected tape units and the core memory, word by word, using only one core memory cycle per word transferred, and only using the program interrupt system in the event of an error or at the end of the block. An interruption system requires that advanced control be halted and arithmetic control allowed to catch up before the interruption takes place. When a short loop is executed in O_1 O_2, the control counter should count up and down to correspond to the actual core address of the word being executed, and a fairly simple interlock is required to enable advanced control to read out the first word of a loop if it happened to execute first the second word of that loop. This is essential for resuming the program after an interrupt, and desirable for normal operation too.

If O_1 O_2 X Y R_2 R_3 and the 12 B-lines are realized as one flow-gating memory which is shared by the core memory, arithmetic control, advanced control, and possibly the input-output control, then the duty cycle of this memory can be very high. If this causes a slow-down in speed, then the B-lines could be held in a second flow-gating memory.

(R. Farrell, W. Gear and D. Gillies)

4. Core Memory

A 1,000-core-test board was modified to allow switching of bit cores at various distances from the driven end. The effect of the discontinuity introduced by a switching core into the transmission line formed by the wired cores can be studied. The possibilities of using core drivers having constant voltage instead of constant current characteristics can be investigated simultaneously.

(K. Smith)

5. Test Equipment

A transistor-aging tester (Dwg. M778) was built and tested. This device subjects 10 transistors simultaneously to 100 mw dissipation (10 ma, 10 v) while monitoring V_{eb} fwd. It is possible to set a threshold on a neon-bulb alarm which indicates that a transistor V_{eb} fwd. has exceeded some desired limit.

The tester uses only one power supply (Illiac + 100) and to this extent needs no special attention. Certain critical circuits have been made sufficiently redundant to prevent destruction of transistors due to tester internal failures.

(K. Smith)

6. Input-Output and Auxiliary Storage

Two versions of magnetic head driving circuits were tested using dummy heads; one was judged suitable for further testing when sample recording heads are received. Two sets of sample heads were ordered: Brush and Davies. Possible means of measuring tape skew (interchannel time-displacement errors) and of reducing its effect on maximum pulse packing density are currently under consideration.

Writing Circuit Tests. Two writing circuits were tested by observing the resulting current waveform through a dummy recording head. The more successful of the two circuits could handle frequencies up to 75 kc (corresponding to approximately 500 pulses/inch packing density at 150 inches/sec tape speed). Since the dummy head was a 10-mh choke, performance of this driver with a low-inductance head should be considerably improved. Heads are available with inductance as low as 1 mh, according to the Ampex local representative. Furthermore, the writing current required for tape saturation with some pulse recording heads is as low as 1 ma, in comparison with the 6 to 10 ma used in the tests.

The following sample heads have been ordered, mainly for use in further driving circuit tests: Brush BK-3202 and BK-3302, and Davies 2001AP and 2001DP.

Tape Skew and Packing Density. In magnetic-tape-recorder operations using a clock track to synchronize the data tracks, the maximum reliable packing density in any channel may be determined by the maximum interchannel displacement error on playback. Packing density may also be limited by such things as dust and oxide build-up, but apparently these effects are not a serious problem at densities of 200 pulses/inch, which seems to be a standard for the industry at present. At any event, skew effects would become the limiting factor under sterile operating conditions, and so are worth considering.

A pertinent question concerns the maximum timing error that can be tolerated between tracks--by what fraction of a bit period or wavelength (on the tape) may the clock pulse be displaced from the nominal bit position, without resulting in erroneous readings? This fraction must be determined experimentally, based on our own standard for reliable operation. Various data available from Ampex literature indicate that the answer will be something less than 0.4 bit period and perhaps something more than 0.1 bit period.

It may be possible to use more than one clock track on one tape, effectively dividing the tape width into small groups of independently clocked channels. This would tend to reduce the maximum interchannel displacement error between channels in any one group, provided that the interchannel displacement error follows some fairly smooth pattern across the tape. (Best results would be obtained if the displacement were linear across the tape, but some improvement would result just so long as the maximum interchannel displacement does not occur between adjacent channels.) If the displacement should be linear, for example, and if some value has been determined for the fraction discussed in the previous paragraph, the packing density in any channel can be increased by a factor n, where n is the number of independently clocked groups of adjacent tracks. Allowing for the increased number of tracks used for clocks and, therefore, not available for data, it is still reasonable to increase the number of bits recorded per inch of tape by a factor of three. For other than linear distributions, this factor is reduced.

The practicality of using several clock tracks will thus depend in part upon the shape of the interchannel displacement curve, which must be determined experimentally. The most promising scheme for determining this involves generating an electrical analog of the displacement of each channel from a single reference channel, smoothing, and recording all such signals simultaneously on a recording oscillograph.

Another important question will be the amount of extra circuitry required by multiple clock tracks. Data recorded simultaneously on several tracks will not be read at the same time. A separate operation is required to resynchronize each row of data before transmitting it on to the receiving equipment. An estimate of the amount of extra equipment required is being prepared at this time.

This multiple clock arrangement leads naturally to another consideration: let each track be self-clocking[1]. Possible complications of this arrangement, including equipment costs, will be investigated in the near future.

There is one recording head arrangement available which puts up to 47 channels on a tape 1.25 inches wide. This involves two separate head stacks, displaced along the tape, with heads of the second writing on the spaces between heads of the first. The same resynchronization system needed for the multiple clock system described above might be of use in this instance. Possible variations in tape length between the two head stacks could be ironed out in the resynchronization system.

(R. Cummins)

A Proposed Method for Coding on Magnetic Tapes and Drums. A number of systems of coding binary information for storage on magnetic tapes and drums are in use. In most of these systems, including both the return-to-zero (RZ) and the non-return-to-zero (NRZ) schemes, the length of time between reversals of current in the writing heads varies over wide limits, and is determined by the number being stored. For example, the direction of writing current as a function of time for the binary number 1101000011, in the system now used for the Illiac drum, is shown in Figure 4(a).

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[1] Richards, R. K., Digital Computer Components and Circuits, D. Van Nostrand, 1957, pp. 332-334.

A negative current records a 1; a positive current records a 0. The shortest current pulse is one bit length, b, and the longest is nb for a sequence of n 0's or n 1's. It is difficult to maintain a uniform writing current for a long string of 0's or 1's, even at modest writing speeds. If the current falls off appreciably, one or more erroneous 1's or 0's may be read at the end of the string.

Similar arguments apply to the system illustrated in Figure 4(b), in which a change of direction of magnetizing current represents a 1; no change represents a 0. In this case the longest pulse length is (n+1)b for a sequence of n 0's.

When one attempts to increase the density of bits by increasing the writing speed, the problem becomes more acute. From a circuit point of view, it would be possible to speed up the current reversal by overdriving, provided the ratio of the longest pulse length to the shortest one could be held to a small value. Several methods of achieving this have been proposed. For example, the bits can be arranged in small blocks, with an arbitrary current reversal at the end of each block[2], but this increases the complexity of coding and does not seem to be practical for restricting the ratio of pulse lengths to, say, a factor of two or three. Another suggestion is the double-pulse method, in which the direction of the changes is used to distinguish between a 0 and a 1.[3] As illustrated in part (c) of Figure 4, positive changes represent 1's and negative changes represent 0's. Reading is done only at the center of the bit cell; the signals generated at the cell edge between two 1's or two 0's are disregarded. Gating of the reading circuit must be done to within at least b/2, but this does not seem to be a serious limitation. The double-pulse method has the distinct advantage of a ratio of only two between the longest and the shortest pulse length. However, the fact that the frequency response of the writing head must be twice that used for the systems of Figure 4 (a) and (b) is a serious disadvantage.

The scheme proposed here is illustrated in part (d) of Figure 4. A change of magnetization at the center of the cell is used to represent a 1; no

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[2] Ibid, p. 326.

[3] Ibid, p. 332.

change to represent a 0, just as for the system of part (b). In addition, an arbitrary change at the bit cell edge is introduced whenever a 0 is to be followed by another 0. Thus, pulse lengths of b, 1.5b and 2b are present, for a maximum ratio of 2, but the frequency response required of the head is the same as for the system of (a).

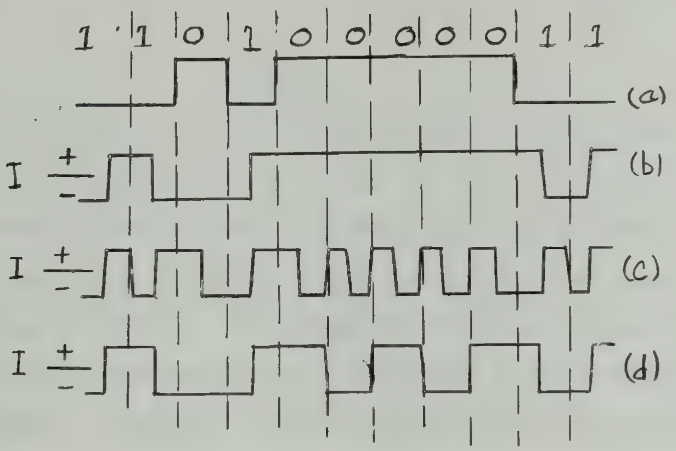

Figure 4

A possible method of writing is shown schematically in Figure 5. Bits to be recorded on a given tape channel are gated into the control circuit at intervals of b, as set by a clock signal, C. A bit, A_1, arriving at time t_o is compared with the previous bit, A_o, and stored in the register R. At $(t_o + b)$, A_1 is gated out of the register and compared with A_2, the newly arrived bit. If A_1 is 1, the OR circuit is actuated and the writing current reverses. If A_1 is 0 and A_2 is 1, nothing happens. If A_1 and A_2 are both 0, the OR circuit is actuated b/2 later, and the writing circuit reverses at $(t_o + 1.5b)$. In addition to the clock pulses, C, another set, C', will be required spaced halfway between the C pulses. Both sets could be derived from a sine wave used to regulate the timing of all channels being recorded, and to produce the clock track recorded on the tape or drum.

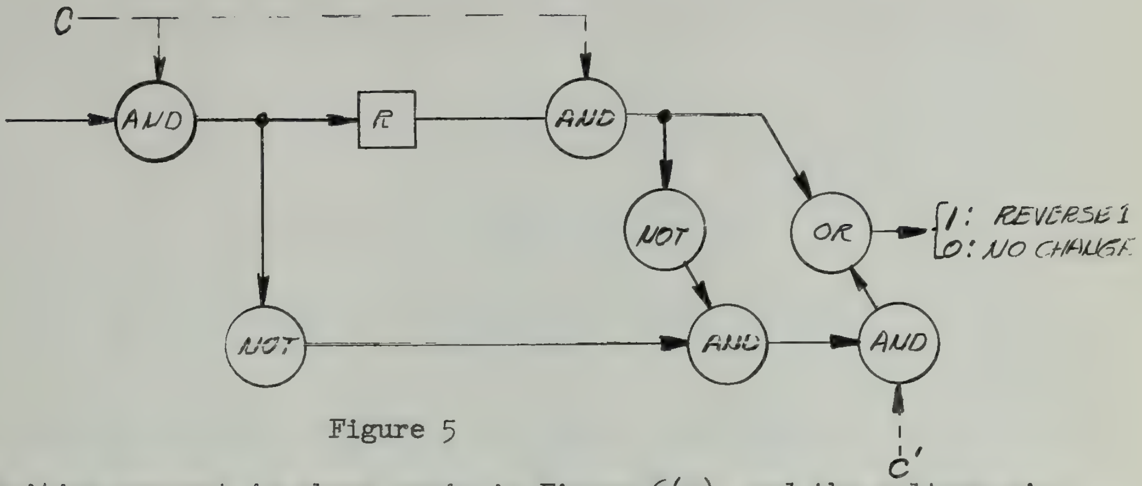

Figure 5

The writing current is shown again in Figure 6(a), and the voltage signals as read under ideal conditions are shown in (b). If the density is increased considerably, by increasing the speed, the voltage pulses are likely to become spread out, as suggested in (c), where solid vertical lines show the voltages that occur during the reading interval. Two smaller voltages, indicated by arrows might cause errors. Methods of eliminating them (besides the obvious idea of using a threshhold) might be based upon some of the following characteristics of the errors:

1. A zero may be misread as a one, but the reverse error is not likely. More specifically, a 100.... sequence might be misread as 110...., or a ....001 sequence as ....011.
2. An erroneous signal at a cell center is always preceded and/or followed by a larger signal in the same direction at the cell edge. A correct signal at a cell center is always preceded and/or followed by either a smaller signal in the same direction or no signal at the cell edge.
3. If all center and edge pulses are read, a voltage of one polarity is always followed by a voltage of the opposite polarity.
4. If the reading strobe should get out of phase so far that cell edges were being read instead of cell centers, a partial check

could be based upon the fact that a pulse of length 2b can occur only between cell centers (a 101 sequence), never between cell edges.

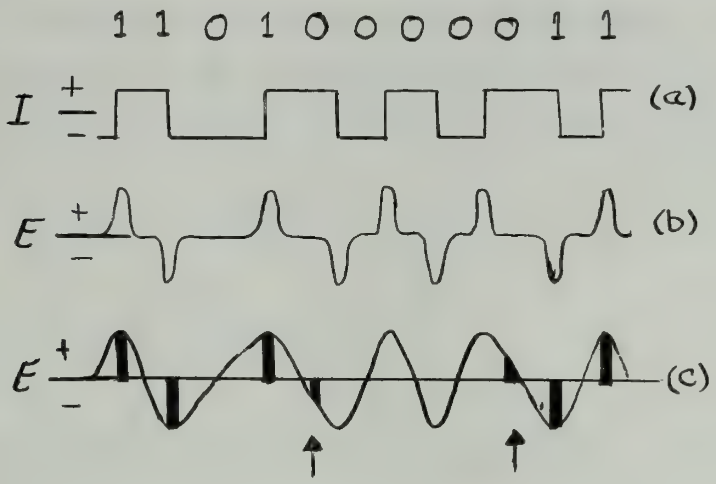

Figure 6

(T. Murrell)

PART II

MATHEMATICAL METHODS

1. Iterative Methods for Solving Systems of Linear Equations

(Supported in part by the Office of Naval Research under Contract N6ori-07130)

The definite symmetric N x N matrix A in the equations $Ax = y$ has Young's property A if there exist two disjoint subsets S and T of the set of first N integers, such that the union of the subsets is equal to this set and if $a_{ij} \neq 0$, then either $i = j$ or i is in S and j is in T. If the matrix A has this property, a coordinate system may be chosen so that

$$A = \left\| \begin{array}{c|c} I_1 & S' \\ \hline S & I_2 \end{array} \right\|$$

where I_1 and I_2 are unit matrices of M and N - M dimensions.

In this coordinate system approximants to the solution of the system of equations $Ax = y$ may be written as

$$\eta^k = \left\| \begin{matrix} \eta_1^k \\ \eta_2^k \end{matrix} \right\| .$$

It has been shown that the vectors

$$\xi^k = \left\| \begin{matrix} \eta_1^k \\ \eta_2^{k+1} \end{matrix} \right\|$$

where the η^k are defined by the recursive relations given by von Neumann (cf. February Monthly Progress Report) can be computed with the use of memory space for the storage of ξ^{k-1} alone and storage for ξ^{k-1} and ξ^{k-2} is not needed. Further, the ξ^k converge faster to the solution of the equations than do the η^k.

(G. Golub)

2. Hydrodynamic Flows with Shocks (Supported in part by the National Science Foundation under Grant G2794.)

A new program was written for solving the system of difference equations

$$mN_k^{n+1} = (1 - \theta_k^{n})mN_k^{n} + \theta^{n}_{k-1}\, mN^{n}_{k-1}$$

$$mN_k^{n+1}\, u_k^{n+1} = (1 - \theta_k^{n})mN_k^{n}\, u_k^{n} + \theta^{n}_{k-1}\, mN^{n}_{k-1}\, u^{n}_{k-1} + r(p^{n}_{k-1} - p_k^{n})$$

$$mN_k^{n+1}\, E_k^{n+1} = (1-\theta_k^{n})mN_k^{n}\, E_k^{n} + \theta^{n}_{k-1} mN^{n}_{k-1}\, E^{n}_{k-1} + r(p^{n}_{k-1}u^{n}_{k-1} - p^{n}_{k}u^{n}_{k}),$$

where

$$p_k^{n} = (\gamma-1)mN_k^{n}(E_k^{n} - \tfrac{1}{2} u_k^{n\,2})$$

$$\theta_k^{n} = \frac{\frac{1}{2}\, r_1(u^{n}_{k+1} - u^{n}_{k})}{1 + r(u^{n}_{k+1} - u^{n}_{k})}$$

$$r = \frac{\Delta t}{\Delta x} ,$$

for the approximate solution of one-dimensional problems of compressible flow.

The problem considered was that of a steady-state shock. For the true solution, the width of the shock is zero. A measure of the width of the shock, as represented by the difference equations at the n^{th} step of the calculation, is a quantity denoted by $2\sigma_n$ (cf. March Monthly Progress Report). The original purpose of the program was to test an upper bound for σ_n^2 which had previously been obtained analytically--that is, to test how well this upper bound approximated σ_n^2.

While the program was being written, a lower bound and another "estimate" can be obtained which are sharper than those furnished by the upper and lower bounds of σ_n^2. Both the upper and lower bounds for σ_n^2 are proportional to n, and another question of interest was whether σ_n^2 is also strictly proportional to n.

In the numerical example which was run, σ_n^2 was found to be very nearly (within 2%), but not exactly, proportional to n. If we write $\sigma_n^2 = \alpha n(\Delta x)^2$, the following is a summary of the numerical results:

upper bound α = .230

lower bound α = .125

"estimate" α = .200

true α = .196 ± 2% .

(C. Farrington)

3. Determination of Flows Behind Shocks (Supported in part by the National Science Foundation under Grant G2794.)

Computations were performed to determine the flow behind a pseudo-stationary shock with an essential singularity. The shock was taken to have an inclination given by

$$\alpha(S) = \alpha_o \qquad 0 \leq S \leq S_*$$

$$\alpha(S) = \alpha_o + K(S-S_*)^{1/2} \qquad S_* \leq S \leq 2S_* .$$

That is, the parametric equations of the shock are

$$\frac{da_1}{dS} = -\cos \alpha(S) \qquad \frac{da_2}{dS} = -\sin \alpha(S)$$

where the constants of integration of these equations are chosen so that

$$a_1(S_x) = \frac{v \cos \chi}{\sin (\alpha_o - \chi)}$$

$$a_2(S_x) = \frac{v \sin \chi}{\sin (\alpha_o - \chi)} .$$

In these equations V is the normal velocity of the shock into still air and is the angle the line connecting the origin and the singular point on the shock makes with the a_1 axis. We further determine K and S_* so that the shock is perpendicular to the a_1 axis at $S = 2S_*$. Thus, K and S_* are determined by

$$\alpha_o + KS_*^{1/2} = \frac{\pi}{2}$$

$$\frac{V \sin \chi}{\sin (\alpha_0 - \chi)} = \frac{2}{K^2}(1 - \sin \alpha_0).$$

The calculations were performed for $\chi = 1^\circ\ 34''$ and $\alpha_0 = 62^\circ\ 6'$ and a V corresponding to a shock with an inverse pressure ratio of $p_0/p_1 = .811$. These are observed values occurring in a particular Mach reflection. It is the purpose of the calculations to see if they lead to pressure and density distributions similar to those observed. In particular, the loci, $\xi_2(S,T)$ = constant, are being studied where the quantity ξ_2 is the inclination of the streak-lines behind the shock relative to the a_1 axis.

(Y. Chow)

4. Program Library (Supported by Office of Naval Research under Contract N6ori-07130)

F-6 Integration of a System of Ordinary Differential Equations with Automatic Control of Integration Interval. This program uses the classical Runge-Kutta method to integrate a system of ordinary differential equations. An estimate of the truncation error introduced during each step of the process is made during the step by comparing the results of the numerical integration with those obtained from a lower order process based on some of the intermediate calculations. The step interval is then shortened or lengthened appropriately so as to keep the truncation error just within a pre-assigned bound subject to the restriction that the step interval should never be made greater than a given maximum value.

(A. Nordsieck)

M-21 Matrix Multiplication. This new matrix multiplication program is an automatic routine which will handle larger matrices than previous programs by virtue of the fact that it uses the magnetic drum for temporary storage of data. It has been written so that no special scaling of the matrices is required.

(R. Polivka)

M-22 Eigenvalues and Eigenvectors of a Symmetric Matrix Using the Methods of Givens and Wilkinson. The method of Givens for finding eigenvalues of symmetric matrices, which was used in routine M-20, has been extended so as to yield the eigenvectors, as well, by use of a technique suggested by Wilkinson.

(C. Gear)

P-17 Maximum Speed Fraction Print to Twelve or Fewer Places Closed with One Program Parameter. This subroutine uses the same entry conventions as P-16 for punching correctly rounded fractions. The punching takes place at the maximum speed possible with the high-speed punch.

(R. Flenner)

PART III

SWITCHING THEORY

1. Distributive Circuit Theory

Three principal results have been obtained in the theory of distributive circuits which do not reach equilibrium. The cyclical behavior of such circuits can best be described in terms of certain elements of the change chart which are called "cyclically spanned". These are elements (α, i), corresponding to join-irreducible elements $\underline{a}$ of the lattice of C states such that there is a cycling vector w having non-zero i'th component w_i, and $(\alpha + w_i, i)$ is also an element of the change chart whose corresponding join-irreducible element is $\underline{a} + w$ which has the same terminal state as $\underline{a}$. Sets of cyclically-spanned changes describe the cycles that occur in the change chart in a way which is analogous to the description of cyclical behavior of the lattice of C states which was provided by the equivalence sets.

It may be shown that in a binary circuit if (α, i) is cyclically spanned and (β, j) is any element such that $(\alpha, i) \leqslant (\beta, j)$, then (β, j) is also cyclically spanned. Furthermore, the corresponding w_i and w_j are components of the same cycling vector w and $(\alpha + w_i, i) \leqslant (\beta + w_j, j)$. In such cases there is a (γ, i) such that $(\beta, j) \leqslant (\gamma, i)$.

(W. Bartky)

2. Time Tolerance Theory

A study is being made of the behavior of circuits under the assumption that the elementary components have time tolerances upon their actions. For each element i two times δ_i and M_i are specified and the assumption is made that if the element becomes excited at some time t, and remains excited, it will act at a time in the interval $t + \delta_i$ to $t + M_i$.

Circuits are classified as being of one of two types:

1. those for which there exists a number r, where $0 < r \leq 1$, such that a unique specified behavior can be achieved only if $\delta_i/M_i \geq r$ for some i, and

2. those for which no such r exists, or in other words, those for which we may make $\delta_i/M_i < r$ for all i and for any $r > 0$ which we may choose.

Asynchronous circuits which are of greatest interest to the designer are of type 2, and a way of designing circuits of this type is being sought.

(J. Shelly)

3. Logical Programming

An idealized computer was developed in order to study logical systems capable of expressing their own syntax. This computer was chosen as one which can easily be described, and yet possesses properties which simplify programming.

A memory location is regarded as containing a symbol (word) and is addressable by an ordered pair of symbols. A single instruction is provided which copies the symbol in one specified memory location into another and jumps to the next instruction. This instruction, therefore, consists of five symbols: two to specify the location copied from, two to specify the location which altered, and one for the jump.

A formal equivalence between this idealized computer and any universal computer (such as a Turing machine) was shown to exist, provided the memory is assumed to contain an infinity of symbols, initially. An investigation is being made of the possibility of writing programs describing the properties of the computer. A theorem has been obtained which applies to programs in which the data are not used to modify the instructions. Such programs may be described by a specification of their action upon data consisting of only unlike symbols. This theorem provides the link between the notation of variables used in mathematics and the more cumbersome notation used in programming.

(D. Muller)

PART IV

ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

Machine Use

During April, specifications were presented for 13 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1137.

1137 Chemistry. Reaction Kinetics of Polymers. A least squares fit will be made to determine the molecular weight and chain transfer constant from measured quantities.

1138 Anthropology. Analysis of Kinship Patters of American Indian Tribes. The problem is a test of the major statistical description of kinship traits of American tribes reported by Driver and Massey in Comparative Studies of North American Indians. These authors used an inspectional technique for arranging a series of phi coefficients describing the presence or absence of kinship traits in various tribes. By this method they derived a scale of kinship-associated traits.

The test of the Driver-Massey conclusions will be through securing a factor analysis of the phi coefficients of the same data. The hypothesis is that the Driver-Massey scale will not be confirmed either because internal inadequacies of their data or because of bias introduced by their inspectional technique. However, if their results are confirmed, it will support one of the first major applications of statistical techniques to anthropological data.

1139 Computer. Partial and Ordinary Differential Equations. This problem consists of two parts. The first part consists of finding a first order solution of the two dimensional Poisson equation $\Delta \Psi = \rho$. The second part is an attempt to find an improved forward facing integration formula of the Runge-Kutta type which permits automatic step modification.

1140 T Economics. Market Factors Influencing the Sale of Gasoline. A factor analysis will be made of the market factors influencing the sale of gasoline.

1141 Aviations Psychology. Statistical Analysis of Human Engineering. This program will be used to calculate frequency distributions, means, absolute sums, sum X^2, and variances from data to be collected at the Aviation Psychology Laboratory in the near future. This data will be produced automatically in punched tape form suitable for direct Illiac input. It will be derived from human engineering experiments in aircraft instrumentation.

1142 T Psychology. A Methodological Analysis of "Assumed Similarity" Scores. Previous research has indicated significant relationships between certain "assumed similarity" (D) scores and certain behavioral and personality characteristics. The present investigation is an attempt to re-analyze these data, using components of the D score rather than the global D measure as previously used. The components needed would be two means, two standard deviations, and the intercorrelations for each pair of scale sheets for which D scores were previously computed. In addition, the scale sheets used will be factor analyzed over all subjects to determine whether there is more than one dimension present. If so, the above components will be computed for the dimensions obtained, rather than for the entire scale sheet as a unit. As in the previous studies, each of the components will be correlated with the available behavioral and personality criteria to determine what relationships exist.

1143 Computer. Flow Behind Shock Front. The problem consists of finding numerical solutions of a flow behind a shock front and then to predict the configuration of some shock fronts.

1144 Psychology. Objective Measurement of Children's Interests. This study is on the objective measurement of children's interests, i.e., an attempt to develop "unfakeable" interest tests for children. The first study is intended to clarify some scoring questions. The second study aims to develop additional tests and to clarify the factors involved in children's responses to such tests. The third study will aim to investigate the "structure of children's interests".

1145 Psychology. Analysis of Depth Perception Tests. The major purpose of this study will be to analyze the interrelationships among 29 measures of depth perception. In the course of previous research, the question arose as to whether or not the wide variety of tests were actually measuring a single homogeneous function. For example, in the perception of depth and distance which is possible with one eye only, the important monocular cues may include relative size, interposition, linear perspective, relative rate of movement, light and shade, and accommodation. These conditions become increasingly important as the discriminations involved occur at greater and greater distances from the subject. A total of 228 unselected college students were tested on 29 visual perception measures. Approximately one week later, these tests were repeated on the same 228 students.

1146 T Electrical Engineering. Network Approximation. Rational polynomials are generally used for approximation of certain magnitude or phase characteristic of realizable electrical networks. The problem concerning the approximation of both magnitude and phase characteristics will be investigated. Illiac can be used to solve the poles and zeros, and also magnitude and phase shift of a network function, especially, in the case of the function with higher order polynomials.

1147 Statistical Service Unit. Product Moment Correlation. The problem is to develop a product moment correlation program which will handle incomplete data problems.

1148 Bureau of Educational Research. Redundancy Problem. This problem is concerned with assessing the amount of overlap between two test batteries in terms of the common variance. The method consists essentially in the generalization of the multiple correlation. Each battery is orthogonalized by the square root method of factor analysis and intercorrelations of the resulting orthogonal variates are obtained. Each of the resulting orthogonal variates in battery A is then predicted by its multiple correlation with all the orthogonal variates in battery B. The average of these multiple R's is a measure of the extent to which battery B can account for the variance in battery A. Similarly, each of the orthogonal variates in battery B is then predicted from A by the multiple correlation; the average of

these represents the extent to which battery A can account for battery B's variance.

1149 Psychology. Personality and Perception. This is a study to determine relationships between perceptual and personality variables, the data being derived from tests involving illusions.

Table I shows the distribution of machine time for the month of April.

TABLE I

	Hrs:Min
Regular Maintenance	36:50
Unscheduled Maintenance	5:56
Drum Engineering	36:32
R.A.R.	5:23
Leapfrog	37:32
Wasted	:00
Use by Departments	
Computer	36:51
Physics	13:38
Control Systems Lab.	96:15
Structural Research	34:43
Struct. Res. (AF 464)	17:32
Theor. and Ap. Mech. (ORD 593 IC)	2:54
Psychology	33:20
Psychology (I.D.P.W. 44-32-66-312)	3:10
Electrical Engineering	6:42
Elect. Eng. (Boeing Aircraft)	:48
Elect. Eng. (AF 3220)	:03
Elect. Eng. (NOBSR 64723)	1:55
Chemistry	66:43
Agriculture	22:59
State Water Survey	4:21
Inst. of Com. Res.	:21
Inst. of Com. Res. (PH 9067C)	2:46
Mech. Eng. (CONVAIR)	:22
U. of Utah (Psychology)	3:02
U. of Iowa (Psychology)	:26
U.S. Navy (Personnel Research)	1:02
Classes	29:47
Demonstrations	2:42
Miscellaneous	28:05
	532:40

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7 a.m. and 11 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 11 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive, from an error standpoint, to look at the periods between 11 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between 11 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. During the 5:30-6:30 period (when the machine is checked) if no errors are found, the time is given to the "running" column. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for April.

TABLE III

Punch Error	3
Control Error	3
Arithmetic Error	1
Memory Error	5
Drum Failure	5
Reader error	3
Unknown	2
Total	22

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
4/1/58	19:10	:50	1	(1) Arithmetic error. 2^{-24} -2^{-20} adder	0	1:08	0
4/2/58	19:41	:19	2	(1) Drum Failure (2) Drum Failure	0	:26	0
4/3/58	19:29	:31	2	(1) Leapfrog Failure 1 → 0 2^{-8} (memory) (2) Punch #1 failed light on B Gate out	0	:37	1
4/4/58	20:00	:00	0		0	:39	0
4/7/58	19:59	:01	1	(1) Bulb in "A" gate punch #1 out	0	:50	0
4/8/58	19:30	:30	2	(1) Unknown (2) Unknown	0	:43	0
4/9/58	19:30	:30	1	(1) Reader control chassis causing error	0	:26	0
4/10/58	20:00	:00	0		0	:48	0
4/11/58	19:40	:20	1	(1) Punch #1 jammed	0	:40	0
4/14/58	19:33	:26	1	(1) Drum Failure	0	:51	0
4/15/58	20:00	:00	0		0	:44	0
4/16/58	19:58	:02	1	(1) Memory error 2^{-4} 0 → 1	0	1:01	0
4/17/58	19:08	:52	3	(1) Clutch on reader "G" loose (2) Clutch on reader "K" seems to catch (3) Memory failure 2^{-8}	0	1:00	1
4/18/58	20:00	:00	0		0	:55	0
4/21/58	19:57	:03	1	(1) Memory error 2^{-8} 0 → 1	0	6:33	1
4/22/58	20:00	:00	0		0	:43	0
4/23/58	19:59	:01	1	(1) Reader "K" light burned out	0	:40	0
4/24/58	19:15	:45	1	(1) Control error	0	:58	0
4/25/58	18:03	1:57	2	(1) Control error (2) Drum Failure	0	1:13	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
4/28/58	19:59	:01	1	(1) Memory failure 2^{-4} $0 \to 1$	0	:44	0
4/29/58	20:00	:00	0		0	:45	0
4/30/58	19:59	:01	1	(1) Drum Failure	0	:41	0
	432:51	7:09	22		0	23:05	3

Reports and Seminars

Seminars

"On the Geometry of Tschebyscheff-Approximation", by Dr. E. Stiefel, Institut fur angewandte Mathematik, Zurich, Switzerland, April 15, 1958.

"On Automatic Tschebyscheff-Approximation", by Dr. E. Stiefel, Institut fur angewandte Mathematik, Zurich, Switzerland, April 17, 1958.

"Gaseous Equilibrium in Stars", by Hokee Minn, April 22, 1958.

"The Synthesis of a Semi-Automatic Data Processing System for Public Utility Revenue Accounting", by Dr. Gerard Salton, Computation Laboratory, Harvard University, Cambirdge, Massachusetts, April 29, 1958.

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Physics

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

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JUL 1 1958
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PART I - HIGH-SPEED COMPUTER PROGRAM
PART II - MATHEMATICAL METHODS
PART III - SWITCHING CIRCUIT THEORY
PART IV - ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

May, 1958

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part through Contract No. AT(11-1)-415 of the Atomic Energy Commission. The contract is supported jointly by the Atomic Energy Commission and the Office of Naval Research. In addition, this work is supported through Contracts N6ori-07130 and Nonr-1834(15), both from the Office of Naval Research.

The University of Toronto is participating in this work through staff members of its Computation Centre.

1. Transistor Circuits

During the past month an effort was made to find new designs for EXCLUSIVE OR circuits. Up to now most of the circuits proposed in the literature, and tried by this Laboratory, used an emitter-base crosscoupled arrangement, preceded by restandardizing amplifiers. This gave rise to at least two collector delays, and as a consequence, to long operation times. A new circuit was tried which is based on an entirely different principle. In essence, a difference amplifier is used, modified in such a way that over some small voltage interval both transistors can be on and then conduct approximately equal currents. The latter effect is obtained by inserting between the constant current source and the emitters a resistor of appropriate value.

Figure 1 shows the circuit. Assume that negative logic is used. When both inputs are 0, or if both inputs are 1, the transistors T_1 and T_2 share equally the current from the constant current emitter source. The collector loads are chosen such that under these circumstances, each collector is held at -4 v by the bumping diode. For different inputs--i.e., a (0,1) or (1,0) combination--one or the other of the transistors T_1 and T_2 will be cut off; the other one thus conducts the full current. The (negative) OR circuit, formed by the remaining two collector diodes, therefore, only gives its more negative -1- output when the incoming signals differ. This output goes into a level shifting diode which drives an output emitter follower.

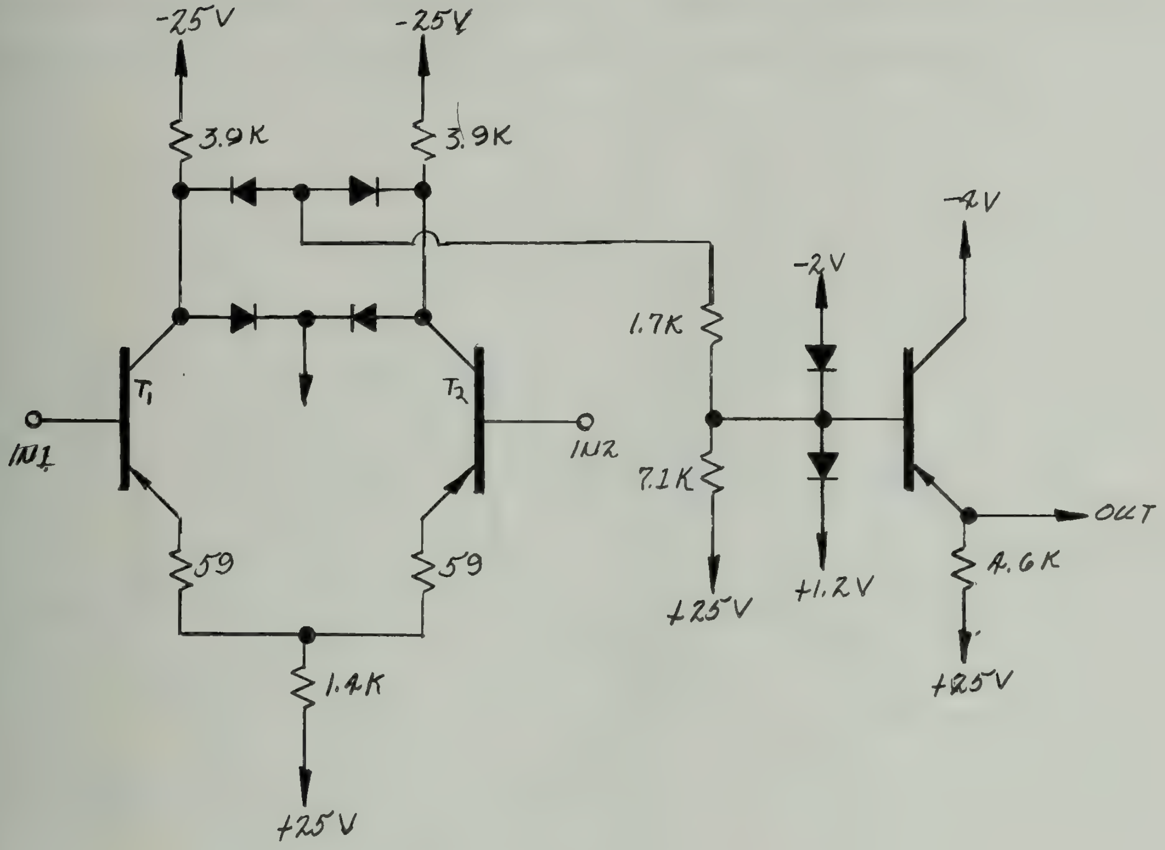
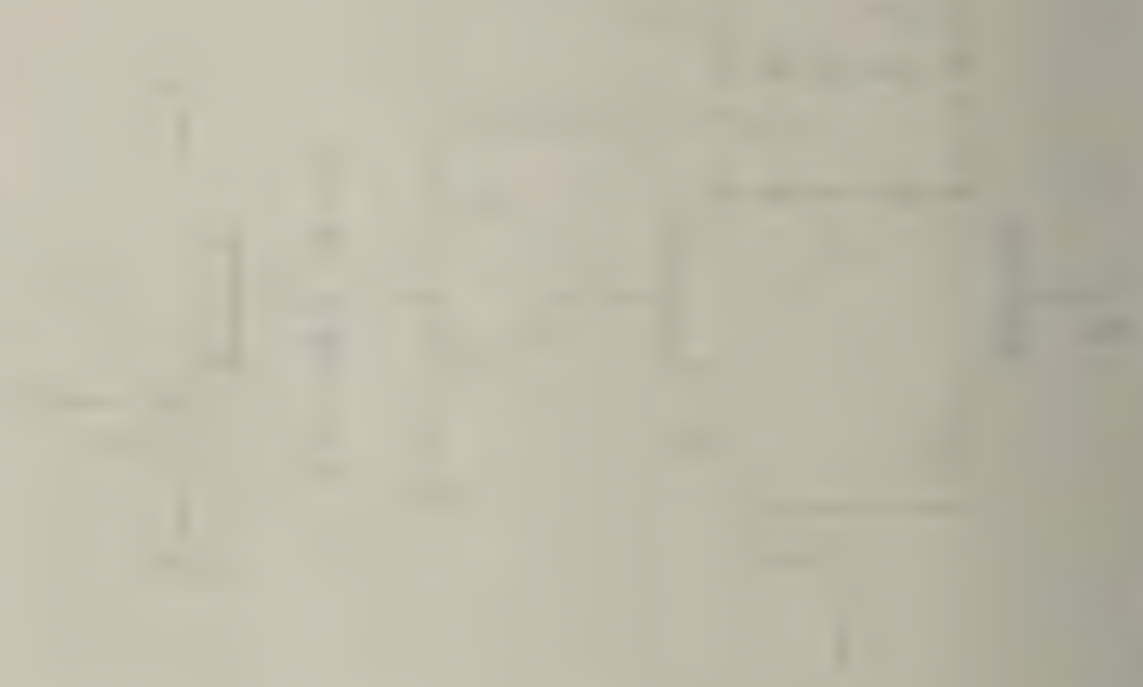


Figure 1

DIFFERENCE-AMPLIFIER EXCLUSIVE-OR

Preliminary tests indicate that about 0.8 v difference can be allowed between nominally equal inputs, and that about 1.2 v difference will be required between nominally different inputs. The resistor values given are only approximate and will be improved after a more careful analysis. No times are available yet, but since only one collector delay is involved, the speed should be approximately that of a NOT circuit.

The design of a flipflop which supplies complementary outputs and has an operation time of about 12 mμs to both ouputs (one of which is a last moving



point and the other one not) has been completed. The arrangement shown in Figure 2 is simply a modified Schmitt trigger with the complemented output taken from the collector of what is ordinarily the emitter follower. The use of a single output point may be considered either an advantage or a disadvantage, depending on the particular application. The possibility of combining the circuit with an AND-OR diode gate driven by a simplified inverter is being investigated.

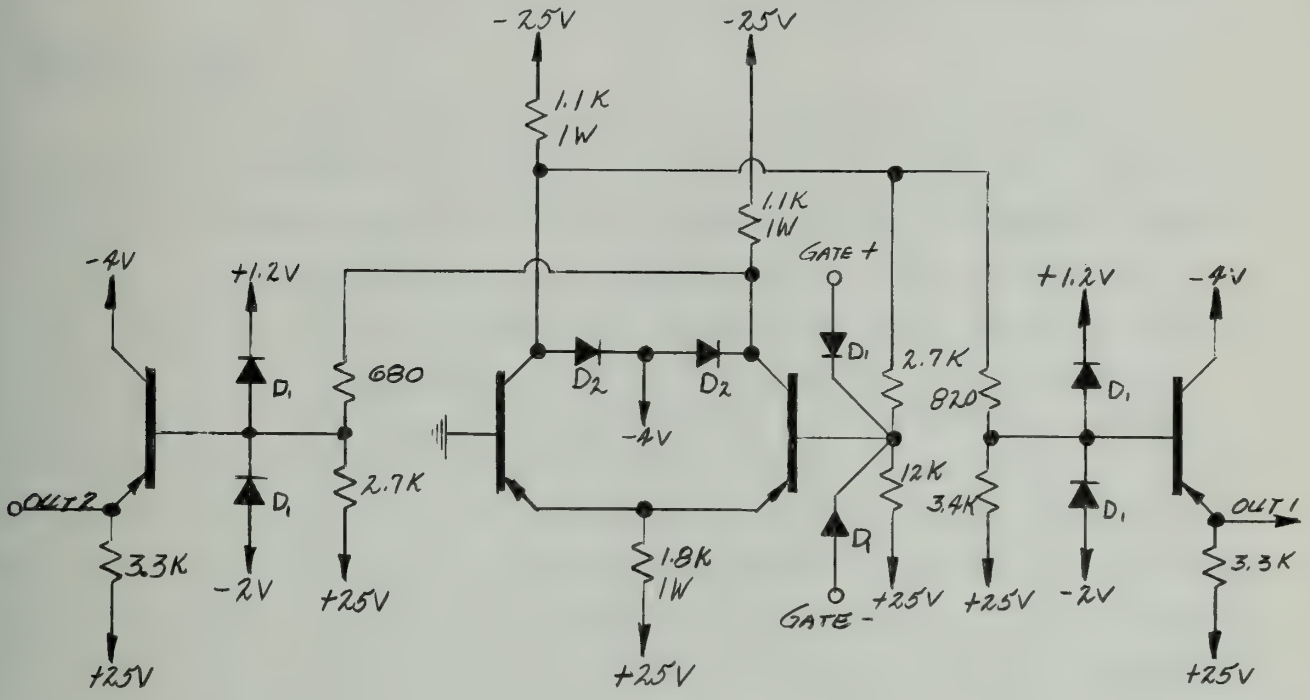


Figure 2

SCHMITT TRIGGER WITH COMPLEMENTED OUTPUTS

Diodes: D1 → Q5-250
D2 → Q10-600

Resistors: Tolerance, ± 3%
1/2 watt unless otherwise specified

Power Supplies: Tolerance, ± 3% on voltages

Transistors: GF-45011; $0.93 \leq \alpha_{DC} \leq 1.0$

Operation Time: 11 to 12 mμs, average

The high-speed tester for transistors has been put into use, and the first modifications have been made. It is used currently for the testing of all incoming Western Electric transistors. A four-bit (eight-flipflop) shifting register using breadboard layout has been completed. The speed being limited by the shifting oscillator, no speed conclusions can be drawn, but a comparison of reliabilities can be made with respect to the older plug-in unit register.

(N. Johnson, Sylvian Ray and N. Wiseman)

2. Control Studies

A method of allowing the program to be interrupted automatically is being planned. This facility is especially useful for code-checking, sequencing the operation of input-output and auxiliary storage devices, and sensing conditions which happen so rarely that continual programmed testing would be wasteful of time. Frequent operations, such as the storage of words during block transfers between the core memory and drum or magnetic tape units, should not use the program-interrupt facility since too much core memory time would be used up. Therefore, the program-interrupt method should be flexible and economical, even if somewhat slow. Except for one or two panel switches, the programmer should have complete control over the conditions which he chooses to cause an interruption. In practice, library subroutines to take remedial steps in case of imparity in block transfers, and to assist in code checking, would probably be used by almost all programmers. Also, when the programmer elects that a certain condition should not cause interruption, he should be able to test for that condition.

(W. Gear, D. Gillies and R. Farrell)

3. Test Equipment

Two 20-transistor 100 mw transistor testers were designed and put into operation. These devices subject the transistors under test to 10 ma (at $V_{cb} = 10$ v) while taking a measure of the largest V_{eb} fwd. of the group. When this measure exceeds a preset value, a flipflop is set and an alarm buzz is given.

To provide control over diode and transistor forward drop measurements, it was found necessary to acquire better low voltage measuring equipment. A 40,000 ohm/volt meter was constructed and calibrated from a secondary standard. It is accurate to within ± 4 mv at a reading of 0.4 volt.

(K. Smith)

4. Arithmetic Unit

A logical circuit was designed which forms $Y = 3X$ where X and Y are binary numbers with digits x_i and y_i. This circuit is simpler than the obvious solution of adding X to 2X.

The performance of a representative stage of this circuit is described by the table below, in which c_{i-1} and k_{i-1} are carries from stage i to the next more significant stage (i-1).

Variable	x_i	c_i	k_i	y_i	c_{i-1}	k_{i-1}
Weight	+3	+1	+1	+1	+2	+2
(0)	0	0	0	0	0	0
(1)	0	0	1	1	0	0
(2)	0	1	0	1	0	0
(3)	0	1	1	0	0	1
(4)	1	0	0	1	0	1
(5)	1	0	1	0	1	1
(6)	1	1	0	0	1	1
(7)	1	1	1	1	1	1

Since the outgoing carries have equal weight, several assignments are possible for cases (3) and (4). However, only the one shown and the one for which the roles of c_{i-1} and k_{i-1} are interchanged lead to redundant conditions. For the assignment shown above, the situation $c_{i-1} = 1$, $k_{i-1} = 0$ never occurs in the output. Since these outputs are the inputs to the next stage, the corresponding situation never occurs at the inputs. Since, furthermore, both carries into the least significant stage are 0, states (2) and (6) are redundant.

The simplified output functions are, then:

$$y_i = x_i \oplus \bar{c}_i k_i$$

$$c_{i-1} = x_i k_i$$

$$k_{i-1} = x_i \vee c_i$$

The equivalent of the tripling circuit is required for the realization of the base 4 division method described in Report No. 82.

(G. Metze)

5. Input-Output and Auxiliary Storage

In the April report, mention was made of a possible method of increasing the pulse packing density on magnetic tape by using several clock channels in place of the usual single clock channel. An essential assumption was that tape skew and related effects were in fact limiting factors in holding packing densities down to the low levels now commonly used. Some reassurance on this point appeared in the April 1958 IBM Journal of Research and Development, in which R. A. Skov[1] described an increase in packing density made possible by partial elimination of some of the mechanical causes of tape skew and flutter.

An estimate of the complexity of the extra circuitry required by multi-clock playback can be obtained from the diagram of the necessary circuit logic. Such a diagram is in preparation and will be described in a separate report. It appears that the equivalent of approximately 450 extra diodes, plus about 70 flip-flops, would be required to resynchronize sixteen information channels on the basis of four information channels to one clock channel.

(R. Cummins)

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[1] Skov, R. A., Pulse-Time Displacement in High-Density Magnetic Tape, IBM Journal of Research and Development, V2, N2, April, 1958.

PART II

MATHEMATICAL METHODS

1. Iterative Methods for Solving Systems of Linear Equations. (Supported in part by the Office of Naval Research Under Contract N6ori-07130)

The iterative method described in the February 1958 Technical Progress Report involves the equations

$$\eta_1 = G\eta_0$$

$$\eta_{k+1} = 2b_{k+1}(G\eta_k + Hy - \eta_{k-1}) + \eta_{k-1}$$

$$b_{k+1} = \frac{1}{2 - \bar{\mu}^2 b_k}$$

$$b_1 = 1$$

and $\bar{\mu}$ a number such that $\bar{\mu}^2 \geq \max\limits_{|x| \neq 0} \frac{x'G'Gx}{x'x}$. Within a computer these equations are replaced by

$$\bar{\eta}_1 = \bar{G} \,\mathrm{x}\, \bar{\eta}_0$$

$$\bar{\eta}_{k+1} = 2\bar{b}_{k+1} \,\mathrm{x}\, (\bar{G} \,\mathrm{x}\, \bar{\eta}_k + \overline{(Hy)} - \bar{\eta}_{k-1}) + \bar{\eta}_{k-1}$$

$$\bar{b}_{k+1} = -\frac{1}{2} \div (-1 + \frac{\bar{\bar{\mu}}^2}{2} \,\mathrm{x}\, \bar{b}_k)$$

where the bars indicate digital numbers, and the pseudo-multiplication and pseudo-division are indicated by x and ÷, respectively.

A difference equation for the quantity $\bar{\eta}_k - \eta_k$ has been derived and solved. The solution will be used to determine the effect of round-off on the accuracy of the solution and on the rate of convergence.

(G. Golub)

2. Hydrodynamic Flows With Shocks (Supported in part by the National Science Foundation under Grant G-2794)

The computationally simplest integration formula for the equations of hydrodynamics is that of P. D. Lax. However, this formula has the disadvantage that it uses a "staggered" lattice, i.e., if the lattice points are $x = k\Delta x (k = 0,1,\ldots)$ at $t = n\Delta t$, then they are $x = (k + 1/2)\Delta x$ at $t = (n+1)\Delta t$.

On the other hand, the direct replacement of derivatives by differences on a rectangular lattice leads to an unstable formula:

$$\rho_k^{n+1} = \rho_k^n + \frac{1}{2} r(\rho_{k-1}^n u_{k-1}^n - \rho_{k-1}^n u_{k+1}^n)$$

$$\rho_k^{n+1} u_k^{n+1} = \rho_k^n u_k^n + \frac{1}{2} r[(\rho_{k-1}^n {u_{k-1}^n}^2 + p_{k-1}^n) - (\rho_{k+1}^n {u_{k+1}^n}^2 + p_{k+1}^n)]$$

$$\rho_k^{n+1} E_k^{n+1} = \rho_k^n E_k^n + \frac{1}{2} r[(\rho_{k-1}^n u_{k-1}^n E_{k-1}^n + p_{k-1}^n u_{k-1}^n) - (\rho_{k+1}^n u_{k+1}^n E_{k+1}^n + p_{k+1}^n u_{k+1}^n)]$$

where $p_k^n = p(\rho_k^n, E_k^n - \frac{1}{2} {u_k^n}^2)$. However, it has been found that a slight modification of this formula results in a stable formula. The modification is to replace ρ_k^n, $\rho_k^n u_k^n$, and $\rho_k^n E_k^n$ in the right hand sides of the first, second and third equations, respectively, by $\theta\rho_{k-1}^n + (1-2\theta)\rho_k^n + \theta\rho_{k+1}^n$, $\theta\rho_{k-1}^n u_{k-1}^n + (1-2\theta)\rho_k^n u_k^n + \theta\rho_{k+1}^n u_{k+1}^n$, and $\theta\rho_{k-1}^n E_{k-1}^n + (1-2\theta)\rho_k^n E_k^n + \theta\rho_{k+1}^n E_{k+1}^n$. The modified system is stable for

$$\frac{1}{2} r^2 v_\mu^2 \leq \theta \leq \frac{1}{2}$$

where $v_\mu = |u_o| + a_o$, $a_o = \sqrt{\gamma(2-1)(E_o - \frac{1}{2} u_o^2)}$ is the sound speed.

Since this system is stable for a range of values of the parameter θ, θ can be chosen in an optimal fashion to satisfy some other criterion, e.g., representation of shock profiles. The shock width $2\sigma_n$ is found to be given by

$$\sigma_n^2 = n(2\theta - r^2 v_o^2)(\Delta x)^2$$

where v_o is the shock speed. This formula, however, is only valid if ρ_k^n is a monotonic function of k, which it is not, in particular, for $\theta = \frac{1}{2} r^2 v_o^2$.

(C. Farrington)

3. Determination of Flows Behind Shocks (Supported in part by the National Science Foundation under Grant G-2794)

Calculations are continuing on the flow behind the shock described in the April Technical Progress Report, the shock with the essential singularity whose inclination is given by the equation

$$\alpha(S) = \alpha_0 \qquad 0 \leq S \leq S_*$$

$$\alpha(S) = \alpha_0 + K(S-S_*)^{1/2} \qquad S_* \leq S \leq 2S_* .$$

The streak lines behind the shock are being determined by solving the equations

$$\frac{\partial a_1}{\partial T}(S,T) = \cos \zeta_2 \qquad \frac{\partial a_2(S,T)}{\partial T} = \sin \zeta_2 .$$

The function $\zeta_2(S,T)$ is determined from the integration of the flow equations.

These results will be used to calculate the isopycnal contours ρ = constant which will be compared to experimental interferograms of Mach reflections.

(Y. Chow)

4. Relativistic Field Equations (Supported in part by the National Science Foundation under Grant G-2794)

For a spherically symmetric space time, the line element may be written as

$$ds^2 = e^{2\varphi} dt^2 - \frac{1}{c^2}(e^{2\chi} dr^2 + r^2 d\theta^2 + r^2 \sin^2 \theta \, d\varphi^2).$$

In this coordinate system the Einstein field equations are

$$R^{\mu}_{\nu} - \frac{1}{2}\delta^{\mu}_{\nu} R = -kc^2 T^{\mu}_{\nu}$$

where

$$k = \frac{8\pi G}{c^2} ,$$

G is the Newtonian gravitational constant; c is the velocity of light; T^{μ}_{ν} is the stress energy tensor; R^{μ}_{ν} the Ricci tensor and R is the scalar curvature.

When the line element is static, that is, φ and χ depend on r alone, these equations reduce to the following system of ordinary differential equations:

$$\frac{c^2}{r^2} - c^2 e^{-2\chi}\left[\frac{1}{r}\left(\frac{1}{r} + 2\varphi_r\right)\right] = + k c^2 T^1_1$$

$$\frac{c^2}{r^2} - c^2 e^{-2\chi}\left[\frac{1}{r}\left(\frac{1}{r} - 2\chi_r\right)\right] = k c^2 T^4_4$$

$$(T^1_1)_r - \varphi_r (T^4_4 - T^1_1) = 0$$

where the subscript r denotes the derivative with respect to r.

For a perfect gas

$$T^\mu_\nu = \sigma u^\mu u_\nu - \frac{p}{c^2}\delta^\mu_\nu \qquad \text{and}$$

$$\sigma = \rho\left(1 + \frac{\epsilon}{c^2} + \frac{p}{\rho c^2}\right)$$

where p is the pressure, ρ is the density and $\epsilon = \epsilon(p_1 \rho)$ is the caloric equation of state of the gas.

If we make the transformation

$$e^{-2\chi} = 1 - \frac{2Gm(r)}{c^2 r}$$

the field equations may be written in the following dimensionless form

$$\varphi_R = \frac{u_c}{R^2}\,\frac{(M + u_c P R^3)}{1 - \frac{2u_c M}{R}}$$

$$M_R = t\left(1 + \frac{\epsilon}{c^2}\right)R^2$$

$$P_R = -t\left(1 + \frac{\epsilon}{c^2} + U_c \frac{P}{t}\right)\varphi_R$$

where u_c is given by $u_c = \frac{kT_c}{\mu H c^2}$, T_c, being a temperature, k Boltzmann's constant and μH the mass of a molecule making up the gas,

$$\rho = \rho_c t$$

ρ_c being a constant of the dimensions of a density, $p = p_c P$

with

$$p_c = u_c \rho_c c^2$$

and

$$R = \alpha r$$

$$\alpha^2 = \frac{c^2 u_c}{4\pi \rho_c G}$$

$$M = \frac{GM}{\alpha c^2 u_c} \quad .$$

These equations are being integrated to find P and M as functions of u_c for various caloric equations of state where further it is assumed that the entropy of the gas is everywhere the same. The latter condition enables one to express t and ϵ as functions of P.

(H. Minn)

4. Program Library (Supported by the Office of Naval Research under contract N6ori-07130).

P 18 Output for the Data Plotter. This subroutine enables the user to plot a series of points with the off-line data plotter. A tape is punched by Illiac which may either be read by the data plotter to plot points, or printed in tabular form if read by the standard printer.

(W. Gear)

PART III

SWITCHING CIRCUIT THEORY

(Supported in part by the Office of Naval
Research under contract N6ori-07130).

A new system has been devised for controlling the gate drivers and other signals which sequence the operations of a computer. One must assume that the correct sequencing of the gates has been described by a change chart showing a chronological ordering of the gates but allowing the possibility of concurrent operation. The present system provides a rule for substituting logical elements for the symbols in the change chart in such a way that the desired sequencing is achieved.

One of the principal difficulties associated with the realization of a change chart is the requirement that the gate signal execute two changes (turning the gate on and off) for each gating operation. This difficulty has been overcome by the present system. To produce the simple sequencing of two gates, we use the connections shown in Figure 1.

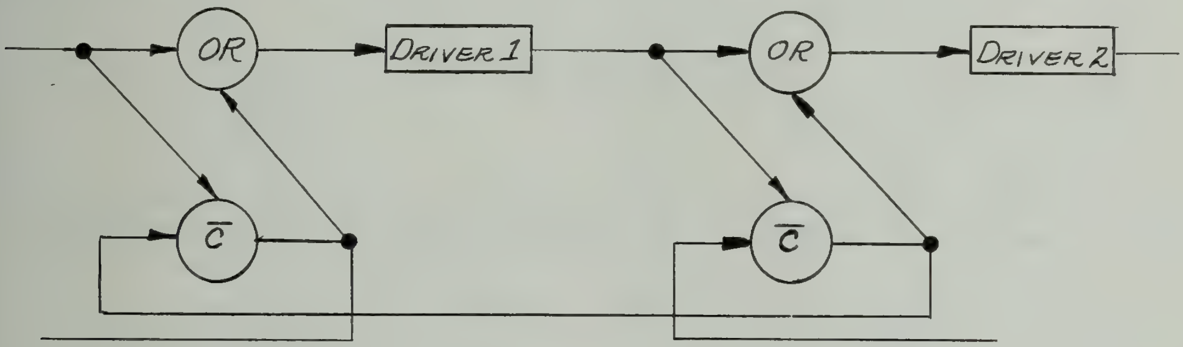


Figure 1

Drivers are assumed to invert the signal and the sequencing circuit will cause driver 1 to gate first, followed by the gating of driver 2. In the quiescent condition, all OR and $\bar{C}$ elements produce the output "1". A "1" arriving at the top input to the first $\bar{C}$ element will initiate the gating.

If driver 1 is to initiate the concurrent gating of drivers 2 and 3, we use the circuit shown in Figure 2.

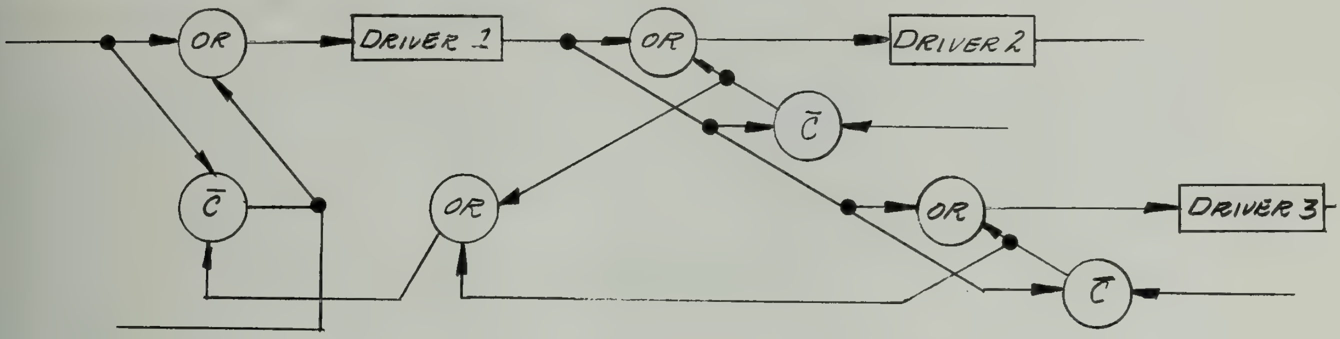


Figure 2

By simple analogy, we may extend the above system to include more than two concurrent gates.

If drivers 1 and 2 are both required to precede driver 3, the circuit shown in Figure 3 may be used.

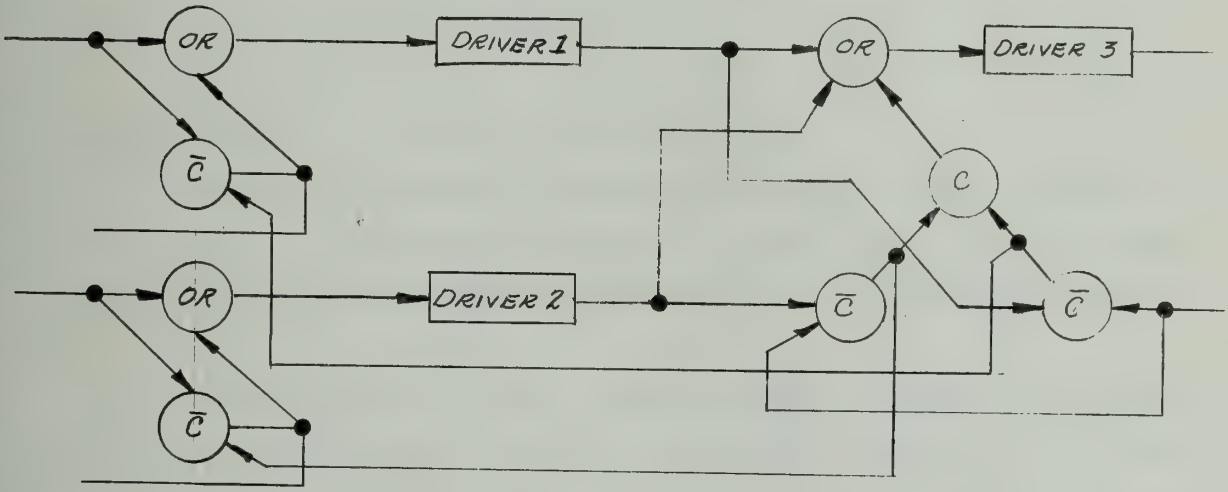


Figure 3

Again, we may extend the system to more than two drivers preceding 3 by simple analogy.

If the same gate is to be used in more than one point in a change chart, we may form a circuit of the type shown in Figure 4 connecting the independent portions in the same manner as before.

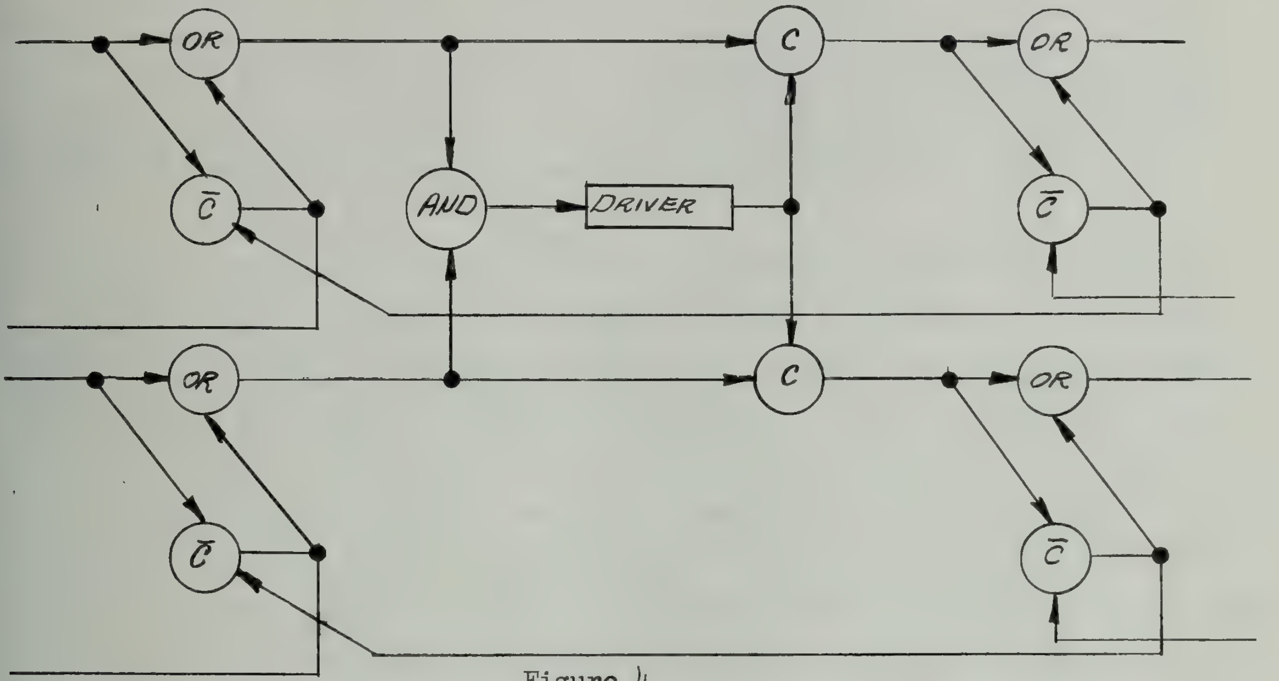


Figure 4

Again, we may extend the circuit to a more general case.

The above design techniques have been checked for speed independence by use of the Illiac. If a cycle containing only two gates occurs in the change chart, however, the C̄ elements must be replaced by OR NOT elements in order to ensure correct sequencing.

This system has the additional advantage that conditional causations in the change chart may be realized quite easily since such conditions (for example, conditions derived from a decoded instruction) may be inserted directly into the OR elements preceding the affected gate drivers.

PART IV

ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

Machine Use

During May, specifications were presented for 11 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1150.

1150 T Psychology. Parental Attitudes Affecting Over- and Under-achievement. This problem involves the analysis of the attitudes of parents of fifth grade students who have been pre-selected according to whether they are over-achievers or under-achievers in school. A number of previous studies have indicated that the degree to which a child utilizes his intellectual ability in the schoolroom is critically dependent on attitudes held by his parents. This study seeks to clarify the nature of these attitudes. The first step in the analysis involves a factor analysis of 72 rating scales by which the parents describe themselves, their spouses, and their children. A centroid factor analysis, and quartimax rotation will be used for this analysis. The next step will be the computation of factor scores for the various self-other descriptions. Finally the D-statistic will be computed for a few selected self-other descriptions.

1151 Computer. Print for Data Plotter. A library subroutine is to be prepared which will simplify the use of the data plotter.

1152 T Electrical Engineering. Theoretical Solutions for Spiral Antennas. Illiac will be used for the numerical evaluation of expressions for the far fields and the arm currents of the equiangular spiral antenna.

1153 T Electrical Engineering. Diffraction Pattern of a Number of Ribbons of Finite Width. The solution for a ribbon in presence of a unit strength filament source is obtained as a function involving Mathieu functions in elliptic cylindrical coordinates. The integrated effect of one ribbon in the presence of the other is obtained by integrating this over the whole width of the strip, i.e. if Π_3 is the

solution then the actual result is given by

$$A = \int_{\text{strip}} \pi_3 \, I \, d z \quad .$$

The integration has to be performed numerically by the computer, but before the integration can be taken up, it is necessary to obtain the eigenvalues and eigenfunctions for Mathieu equations of given arguments which can be evaluated from a continued fraction expression and the recursion formula.

1154 T Structural Research. Computation of Elastic Moment Coefficients in a Reinforced Concrete Box Culvert. By means of a modified moment distribution method, equations have been obtained for computing the elastic moment coefficients in a reinforced concrete box culvert, taking into account the actual thicknesses of the members, assuming the corners to be infinitely stiff.

1155 T Theoretical and Applied Mathematics. Moving Mass on String. This program evaluates a series expression, giving the motion of a mass on a string.

1156 Sociology and Anthropology. Academicians' Conception of Academic Disciplines. In a preliminary study of conceptions of academic fields of endeavor, responses on 18 semantic differential scales for each of 6 selected academic disciplines have been obtained from 160 University of Illinois faculty members. As a part of the analysis of results, a factor analysis will be made of responses for each of the six disciplines.

1157 T Animal Science. Nitrogen Utilization by Sheep. A study has been made of the utilization of non-protein nitrogen (urea) as opposed to N utilization from soybean oil meal and N in dried activated sewage sludge. The utilization of these various sources of N is measured in terms of growth and feed efficiency with lambs.

1158 Civil Engineering and Theoretical and Applied Mathematics. Large Deflections of Circular Plates. The governing differential equations for large deflections of symmetrically-loaded circular plates are non-linear equations which have been solved rigorously for only a few special types of loading and boundary conditions. A

procedure has been devised which will yield solutions for any types of loading and boundary conditions. The governing differential equations are solved by the method of infinite series. Substitution of these assumed series with unknown coefficients V_j, U_j, into the differential equations yields two recurrence relationships of the following form:

$$V_{n+2} = -\frac{2n}{n+2} V_{n+1} - \frac{n(n-1)}{(n+1)(n+2)} V_n - \frac{J}{(n+1)(n+2)} \sum_{i=0}^{n} U_i U_{n-i}, \quad n=0,1,2,..$$

$$U_{n+2} = \frac{-2n}{n+2} U_{n+1} \frac{-n(n-1)}{(n+1)(n+2)} U_n + \frac{1}{(n+1)(n+2)} \sum_{i=0}^{n} V_i U_{n-i}, \quad n=0,1,2,...$$

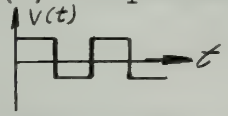
These recurrence relationships, together with the boundary conditions, form a system of transcendental equations, the solution of which permits the evaluation of the unknown coefficients in the series. The solution of these transcendental equations can be found on Illiac using an iterative procedure.

1159 T Finance. Factors Affecting Equity Financing. The problem is to determine the important factors which have affected equity financing of large American business corporations from 1946 to 1956. Multiple correlation will be found.

1160 Physics. Motion of a Particle in a Periodic. It is proposed to study systematically the solution of the non-linear differential equation

$$\frac{d^2x}{dt^2} + U(t) \alpha x^3 = 0,$$

where α is a constant, and U(t) the periodic function:



Of particular interest is the study of the soltuion of the equation around the singular points, and the investigation of the possibility of "islands" in the phase plane. The numerical integration of the equation will be carried out using the Runge-Kutta method (Library Routine F1).

Table I shows the distribution of machine time for the month of May.

TABLE I

	Hrs:Min
Regular Maintenance	32:54
Unscheduled Maintenance	5:24
Drum Engineering	41:48
R.A.R.	7:47
Leapfrog	41:21
Wasted	:00
Use by Departments	
Computer	34:27
Physics	40:32
Control Systems Lab.	83:50
Structural Research	46:22
Struct. Res. (AF 464)	21:30
Theor. and Ap. Mech. (ORD 593 IC)	1:40
Psychology	15:08
Psychology (I.D.P.W. 44-32-66-312)	:57
Psychology (U.S.P.H. 1774)	:10
Psychology (U.S.P.H. M1733)	1:20
Electrical Engineering	6:23
Elect. Eng. (NOBSR 64723)	2:36
Elect. Eng. (SC 74898)	2:59
Elect. Eng. (Boeing Aircraft)	6:00
Chemistry	30:00
Agriculture	15:01
Mech. Eng. (CONVAIR)	:12
State Water Survey	3:52
Inst. of Com. Res. (9067 C)	:14
Michigan State University	2:58
University of Utah (Psychology)	4:39
U. S. Navy (Personnel Research)	:28
Classes	41:09
Demonstrations	:30
Miscellaneous	22:34
	514:45

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7 a.m. and 11 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 11 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive, from an error standpoint, to look at the periods between 11 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between 11 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. During the 5:30-6:30 period (when the machine is checked) if no errors are found, the time is given to the "running" column. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for May.

TABLE III

Memory	2
Reader	1
Control	4
Drum	5
Unknown	3
Input-Output	1
Scope	3
Total	19

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
5/1/58	19:59	:01	1	(1) Input-Output automatic swith inoperable	0	:40	0
5/2/58	19:32	:28	2	(1) Drum failure (2) Unknown	0	:38	0
5/5/58	19:26	:34	2	(1) Drum failure (2) Memory failure 2^{-4} 0 ->1	0	:40	0
5/6/58	19:11	:49	2	(1) Intermittent filament in memory control chassis V-21 (2) Further manifestations of above difficulty	0	:57	0
5/7/58	17:43	2:17	5	(1) Further manifestations of above difficulty (2) Further manifestations of above difficulty (3) Drum failure (4) Unknown (5) Scope would not advance	0	1:36	0
5/8/58	20:00	:00	0		0	:39	0
5/9/58	20:00	:00	0		0	:46	0
5/12/58	19:59	:01	1	(1) Scope error	0	:43	0
5/13/58	19:53	:07	1	(2) Film advance not working in scope	0	1:08	0
5/14/58	20:00	:00	0		0	1:10	0
5/15/58	20:00	:00	0		0	1:13	0
5/16/58	20:00	:00	0		0	1:02	0
5/19/58	20:00	:00	0		0	1:35	0
5/20/58	20:00	:00	0		0	:40	0
5/21/58	19:01	:59	2	(1) Drum failure (2) Leapfrog memory error 2^{-4} 0 ->1	0	3:25	1

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
5/22/58	19:58	:02	2	(1) Light on reader "K" burned out (2) Unknown	0	1:00	0
5/23/58	20:00	:00	0		0	1:01	0
5/26/58	20:00	:00	0		0	:42	0
5/27/58	20:00	:00	0		0	:50	0
5/28/58	18:56	1:04	1	(1) Drum failure	0	:44	0
5/29/58	20:00	:00	0		0	:40	0
TOTALS	413:38	6:22	19		0	21:49	1

Reports and Seminars

Seminars

"Minimization of a Function of N Variables", by Professor D. B. Gillies, May 6, 1958.

"Continued Fractions and Their Use in Numerical Analysis", by Jack Goldberg, May 13, 1958.

"Some Remarks About 'Asynchronous' vs. 'Speed-Independent' Circuit Designs", by Dr. G. Metze, May 20, 1958.

"The Choice of Step Size in Runge-Kutta Type Integration Routines", by C. W. Gear, May 27, 1958.

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Physics

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM

PART II - MATHEMATICAL METHODS

PART III - ILLIAC USE AND OPERATION -
GENERAL LABORATORY INFORMATION

June, 1958

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part through Contract No. AT(11-1)-415 of the Atomic Energy Commission. The contract is supported jointly by the Atomic Energy Commission and the Office of Naval Research. In addition, this work is supported through Contracts N6ori-07130 and Nonr-1834(15), both from the Office of Naval Research.

The University of Toronto is participating in this work through staff members of its Computation Centre.

1. Basic Circuits

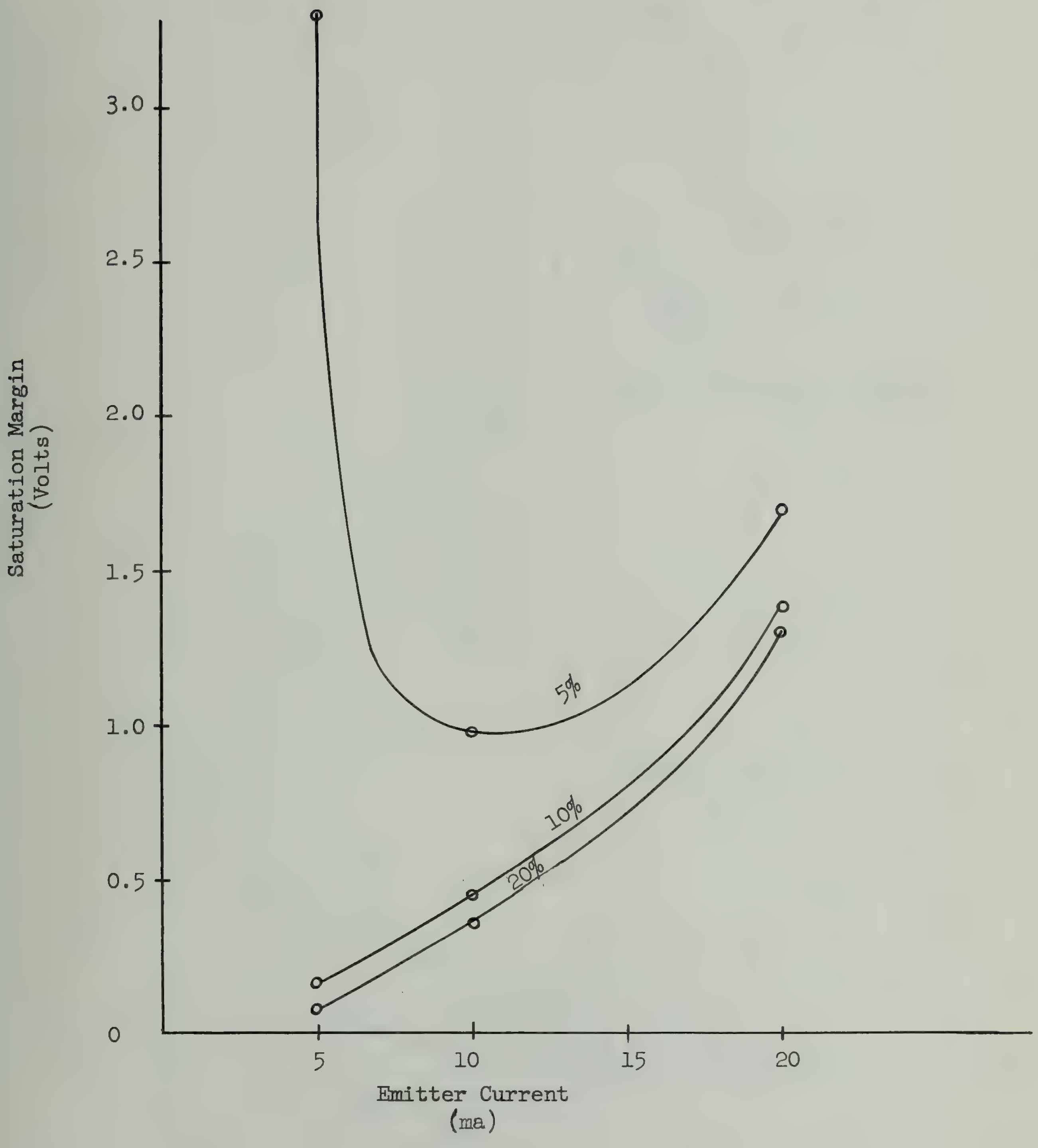
In order to estimate transistor performance under drift conditions an investigation was made to correlate switching speed and saturation margins. Figure 1 shows the increase in time to reach one-half amplitude relative to an 8 v saturation margin for several emitter currents. Figure 2 gives the delay time as a function of the same variables. The major part of the decrease in switching speed appears to be due to the increase of the total minority charge in the base region rather than the increase in collector capacity by collector depletion layer narrowing. This statement is based on collector capacity measurements made previously.

With the adoption of positive logic the EXCLUSIVE OR circuit described in last month's progress report becomes an EQUIVALENCE circuit. A positive logic EXCLUSIVE OR has been devised and built; it is shown in Dwg. S-784. As can be seen, two difference amplifiers are used to generate amplified versions and amplified complements of the input signals A and B and collector logic is used to form $A\bar{B} \vee \bar{A}B$. The operation time of this circuit for a .6 v threshhold (maximum required input signal) was found to be less than 10 mμs. Inputs may lie anywhere in the range from ± 0.6 v to ± 2.2 v for satisfactory operation.

(S. Ray and N. Wiseman)

2. Over-All Design

It was decided that, unless the cost is prohibitively expensive, two more fast-access registers (in addition to R_2 and R_3) should be included. It is



Percent increase in time required to reach 1/2 amplitude for a switching circuit (relative to the switching time at 8 v saturation margin)

Figure 1

Saturation margin versus increases in delay time for a switching circuit to reach 1/2 amplitude relative to switching time at 8 v saturation margin

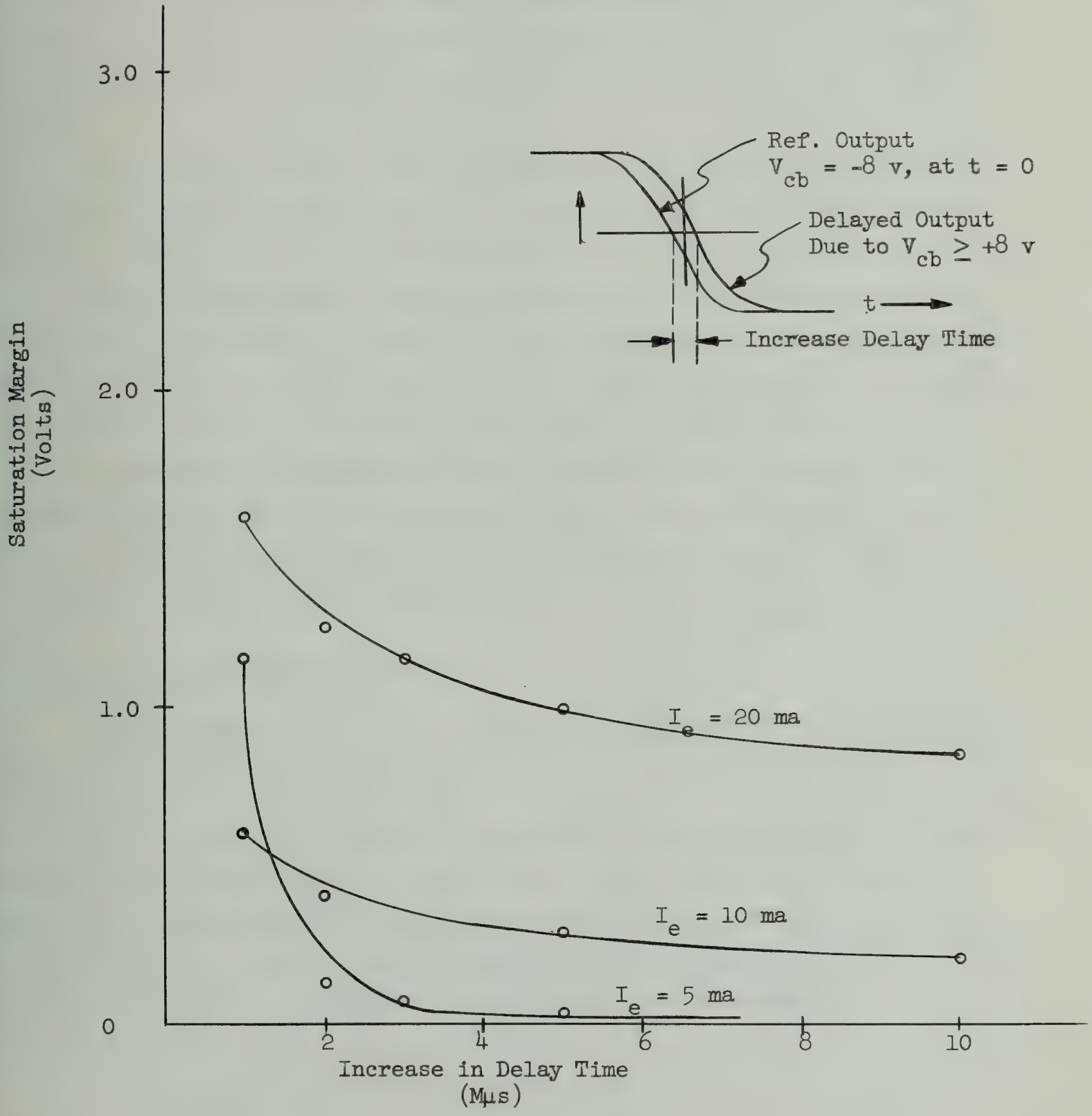


Figure 2

possible to include these in the addressing system because, if B = 0, 1, 2 or 3, the C-digits can be used as address digits as well. Other addressable registers would include a clock register (slow speed counter), an interrupt register, and perhaps a mask for the interrupt register.

In a computer which multiplies beginning at the least significant end of the multiplier, and generates double precision products, non-standardized floating point multiplication is slower than standardized multiplication. Because of this, and the fact that non-standardized floating point requires more equipment, it is proposed that non-standardized arithmetic be not wired in, but be made easy to program.

The control counter, which indicates the position of advanced control, must be able to count up and down. This facilitates program interruption, and allows fast loops to be executed starting with either word in the loop.

For the maintenance of the drum and magnetic tapes which have parity bits, it should be possible to record in such a manner that the parity check will fail. Checks which set an indicator or cause a program interrupt are more useful, for maintenance purposes, than those which cause the computer to stop.

A programmer who manages to use a certain section of magnetic tape at the highest possible duty cycle, can wear out the tape at that point in about a minute. It is, therefore, proposed that all references to magnetic tape be made via a library subroutine which will prevent this misuse.

(R. Farrell and D. Gillies)

3. Input-Output and Auxiliary Storage

Test Equipment. In testing input-output circuits and components, particularly magnetic recording heads and head driving circuits, it is often desirable to have a source of pulses available with which information flow to or from a magnetic tape unit or other piece of equipment can be simulated. For test purposes the basic pulse repetition rate should be variable over a wide range, and it should be possible to simulate any arbitrary configuration of 1's and 0's for a duration of several pulses. Design of such a "Programmed Pulse Train Generator" was started this month. The device consists of the following basic components:

1. An oscillator or clock pulse generator, with frequency variable over a wide range;
2. A cyclic counting mechanism, probably mod 16;
3. A decoding network, to select one of 16 lines depending on the state of the counter;
4. A set of 16 manual switches, each of which may be set independently to "1" or "0";
5. An OR circuit whose output at any instant is "1" or "0" depending on the setting of the switch selected at that time.

The oscillator and most of the switching circuits have been built and tested. A counter has been designed using standard flipflops, but has not been tested. Tests to date have involved only stead-state levels with manually switched inputs; now measurements of rise times of output pulses have been made.

Commercial Input-Output Equipment. A visit was made to the main plant of Potter Instrument Company, manufacturers of input-output equipment. A Potter 906 transistorized high-speed magnetic tape unit was seen in operation; the manufacturer claimed speeds up to 75 inches/second (using 1.25" tape), up to 47 channels, and up to 500 pulses/inch per channel for this machine. A Potter line printer was also on display, capable of printing 10 lines/second of alphanumeric data, with 120 characters/line.

Sample recording heads were received from both Brush and Minneapolis-Honeywell.

(R. Cummins)

PART II

MATHEMATICAL METHODS

1. Iterative Methods for Solving Systems of Linear Equations

(Supported in part by the Office of Naval Research under Contract N 6ori-07130)

In previous months we have considered the von Neumann scheme for solving the equation Ax = y. The scheme consists of generating the sequence of vectors

$$\eta_{k+1} = 2b_{k+1}(G\eta_k + Hy - \eta_{k-1}) + \eta_{k-1} .$$

We now consider the above iteration scheme where $b_{k+1} = b$ for all k so that we generate the sequence

$$(1) \quad \eta_{k+1} = 2b(G\eta_k + Hy - \eta_{k-1}) + \eta_{k+1} .$$

Within the computer, however, we generate the sequence

$$(2) \quad \bar{\eta}_{k+1} = 2\bar{b} \times (\bar{G} \times \bar{\eta}_k + \overline{Hy} - \bar{\eta}_{k-1}) + \bar{\eta}_{k-1}$$

where bars indicate digital representation and x the pseudo-operation of multiplication. Equation (2) can be rewritten as

$$(3) \quad \bar{\eta}_{k+1} = 2\bar{b}(\bar{G}\,\bar{\eta}_k + \bar{H}y - \bar{\eta}_{k-1}) + \bar{\eta}_{k-1} + \delta_k$$

where the components of δ_k represent the roundoff in pseudo multiplication. Since

$$x = 2\bar{b}(Gx + Hy - x) + x \;, \qquad \text{we have}$$

$$d_{k+1} = 2\bar{b} + (1-2\bar{b})d_{k-1} + v_k \qquad \text{where} \qquad d_k = \bar{\eta}_k - x \qquad \text{and}$$

$$v_k = 2\bar{b}\,[(\bar{G} - G)\,\bar{\eta}_k + \overline{Hy} - Hy| + \delta_k .$$

By solving a non-homogeneous system of finite difference equations, it is possible to obtain an upper bound for d_k. Now if A has property A, it is possible to modify the above scheme so that we have the Young Successive Over-relaxation Scheme. Upper bounds have been obtained for the error vector in this case, too.

(G. Golub)

2. Relativistic Hydrodynamics (Supported in part by the National Science Foundation under Grant G2794)

A paper entitled "On Circulation in Relativistic Hydrodynamics" has been completed. This paper will be presented to the International Congress of Mathematicians in Edinburgh and will be submitted to a technical journal for publication.

In this paper it is shown that in relativistic hydrodynamics the analogue of the circulation in classical theory is the integral

$$C = \int e^{-\varphi} u_\alpha \, dx^\alpha$$

where φ is a specified function of pressure and density, u_α are the covariant components of the four velocity of the fluid and the integral is taken around a closed curve travelling with the fluid. This integral is similar to an integral given by A. Lidenerowicz in his book, Theories Relativistes de la Gravitation et de L'Electromagnetisme. The two integrals differ in the definition of $e^{-\varphi}$.

The necessary and sufficient conditions for C to vanish are shown to be that the flow be irrotational and isotropic. The necessary and sufficient conditions for C to be a constant of the motion is that the pressure be a function of density alone at every point in space-time occupied by the fluid. This condition is shown to be violated when a shock is present. Results for similar integrals taken around vortex lines are also obtained. The relations between these results and Bernoulli's theorems are discussed.

PART III

ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

Machine Use

During June, specifications were presented for 19 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1161.

1161 Bureau of Educational Research. Covariance Routine. This program computes the item covariance from the difficulty (percentage of pass) and tetrachoric correlation between items.

1162 Psychology. Relation of House Drawings to Intelligence and School Achievement. On entering first grade, each student made a sketch of a house which was scored on a 15-item check sheet by both his teacher and a professional school psychologist. Later in the year, test scores were obtained on the California Test of Mental Maturity on American School Achievement Tests, and on a behavior rating schedule. Product moment correlations will be obtained for individual classes (each having a different teacher) and for the combined classes. Centroid factor analysis will be run on the latter matrix.

1163 T Structural Research. Stresses in a Layered System. Each layer of the half-space, though itself homogeneous, may have physical properties and thickness different from the others. The lowermost layer extends to infinity. Stresses and displacements are expressed as definite integrals of a product of three functions, two of which are known, and the third can be computed as a function of the boundary conditions. For n layers, 4n-2 simultaneous linear algebraic equations are solved for each value of the independent variable, to obtain this function. Numerical quadrature is used to compute the integral.

The present program will evaluate stresses and displacement at desired points in a given layered system due to loading either concentrated or uniformly distributed over a circular area.

1164 T Animal Science. Comparative Study of Avian and Mammalian Growth. Various pituitary hormones obtained from birds and animals were injected into rats separately and in combination. The effect on growth and on several other variables will be determined.

1165 Student Counseling Service. Preliminary Analysis of Activity Preference Checklist. Several inter-correlation matrices will be obtained to yield for several sub-groups of students, split-half reliability coefficients, correlations of various scale scores with several socio-econmic measures, and correlation of various scales with relevant freshman guidance test sub-scores.

1166 T Management. Sulfuric Acid Production as an Indicator of Business Conditions. Correlations are obtained with 16 other business indicators for a time series of 152 months, allowing for leads and lags of 0 to 6 months. Means, variances, and best least-squares lines are also obtained.

1167 Student Counseling Service. Relative Contributions of Two Grammar Tests to Prediction of Academic Success. Multiple correlations are obtained between the "Sentences" test of the Differential Aptitude Test battery, and the "Mechanics of Expression" test from the Cooperative English test, with rhetoric grades and grade-point averages as criteria.

1168 T Theoretical and Applied Mechanics. Determination of Stress Relationships at the Junction of a Spherical Shell in a Cylindrical Nozzle. The solution will be attempted in two ways: (1) Solve the controlling equilibrium equations by finite differences; and (2) Solve a system of linear algebraic equations obtained from minimizing energy.

1169T Physical Education. Body Density and Fat Changes with Exercise. Inter-correlations and multiple and sub-multiple correlations will be obtained between 30 muscular, fat and bony measures before and after a program of exercise conditioning.

1170 Psychology. Reactive Inhibition and Extraversion-Introversion. It is desired to test the hypothesis proposed by Eysenck that the hypothetical neurological variable, reactive inhibition, is one of the bases for individual differences in extraversion-introversion. Sixty-two subjects were tested for eight hours each. Empirical measurement of "conditionability" is made by a factor analysis. Similarly, reactive inhibition will be defined in terms of a factor analysis of eight different experimental settings thought to indicate it. Then a joint factoring of selected indices of reactive inhibition and a dozen personality variables including measures of extraversion-introversion will determine the degree of co-loading.

1171 T Electrical Engineering. Network Sensitivity Figures. Analytical approximations to time and frequency sensitivity figures will be compared with more accurately calculated values.

1172 Physics. Detection Probability of Neutral Pimeson Decay. An experiment has been done to determine the threshold energy of photoproduction of neutral mesons from hydrogen and helium in the hope that it may reveal the existence of the heretofore unknown singlet neutral pimeson. To analyze the experimental data and determine the threshold energy requires the calculation of:

A) Bremsstrahlung spectra from the betatron;
B) the detection efficiency of a neutral pi meson by two Cerenkov coincidence counters; this is the evaluation of a definite integral;
C) the best fit to the experimental data to determine the threshold energy.

1173 T Chemistry. Quadrupole Coupling Constants of Ions in Crystals. The vectors from some central ion in a crystal to all surrounding ions within a given radius are computed. Various functions of these vectors, such as the quadrupole coupling constant are then computed.

1174 Psychology. Intercorrelation and D^2 on Clinical Data. This is an investigation of the structure of several commonly used sets of psychotherapy research variables and two general descriptive statistical approaches.

1175 T Economics. Macro-economic Models for the Italian Economy 1946-1956. The parameters for two distinct models of an economy (relating to such things as consumption, net investment, net national product, government expenditures, net foreign investment, cost of living index, etc.) will be determined statistically.

1176 Water Survey. Drop Inlet Spillway Study. This is a data reduction problem to obtain head loss coefficients and pressure distribution to determine the best proportions for spillways which have unique hydraulic characteristics.

1177 T Calculation of Cross Sections from Yield Curves. Cross sections are for the reaction

$$ {}_5B^{11} + \gamma \rightarrow \pi^- + {}_6C^{11} \quad , $$

the photoproduction of negative pions from 140 Mev to 300 Mev.

1178 Mathematics. Prime Number Formulas. Several formulas yielding a high density of primes will be investigated empirically.

1179 Computer. Interstitial Defects in a Linear Chain. One or two additional atoms are inserted at interstitial positions in a linear chain of molecules. In the mathematical model, interaction is confined to adjacent atoms. A Monte Carlo procedure is used to generate an ensemble of configurations of the perturbed chain approximating the Boltzmann distribution, and mean displacements are determined by averaging over this ensemble. The computed solution is compared with the known solution to see how quickly the method produces a reasonably good estimate when certain parameters are varied. This will be useful for a later program for a more general 3-dimensional case.

Table I shows the distribution of machine time for the month of June.

TABLE I

	Hrs:Min
Regular Maintenance	28:56
Unscheduled Maintenance	7:50
Drum Engineering	38:47
R.A.R.	9:31
Leapfrog	36:23
Wasted	:15
Use by Departments	
Computer	24:09
Physics	29:26
Control Systems Lab.	73:39
Structural Research	42:55
Struct. Res. (AF 464)	46:42
Psychology	33:11
Psychology (PH 1733)	2:37
Psychology (USPH 1774)	:26
Psychology (44-33-66-312)	:56
Electrical Engineering	17:22
Elect. Eng. (Boeing Aircraft)	:40
Elect. Eng. (AF 3220)	:09
Chemistry	39:15
Economics	18:58
Agriculture	12:54
State Water Survey	4:54
Inst. of Communications Res.	3:18
Inst. of Com. Res. (PH 9067C)	2:08
Mech. Eng. (ORD 1980)	:06
Michigan State University (Economics)	7:55
U. of Iowa (Public Health)	2:24
Demonstrations	1:08
Miscellaneous	27:52
	514:46

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7 a.m. and 11 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 11 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive, from an error standpoint, to look at the periods between 11 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between 11 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. During the 5:30-6:30 period (when the machine is checked) if no errors are found, the time is given to the "running" column. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for June.

TABLE III

Arithmetic	1
Reader	1
Punch	2
Power	1
Drum	3
Total	8

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
6/2/58	20:00	:00	0		:00	:59	0
6/3/58	20:00	:00	0		:00	1:20	0
6/4/58	19:59	:01	1	(1) Punch # 4 punched extra zeros	:00	:44	0
6/5/58	20:00	:00	0		:00	:39	0
6/6/58	20:00	:00	0		:00	:41	0
6/9/58	20:00	:00	0		:00	2:27	0
6/10/58	20:00	:00	0		:00	1:18	0
6/11/58	19:45	:00	0		:15	:56	0
6/12/58	20:00	:00	0		:00	1:04	0
6/13/58	20:00	:00	0		:00	1:16	0
6/16/58	13:47	6:13	2	(1) Leapfrog failure--arithmetic error (2) Reader error--Reader "G"	:00	:57	1
6/17/58	19:59	:01	1	(1) Punch #4 punched extra 8 holes	:00	1:01	0
6/18/58	20:00	:00	0		:00	:40	0
6/19/58	19:45	:15	1	(1) Power failure	:00	1:58	0
6/20/58	20:00	:00	0		:00	:39	0
6/23/58	19:20	:40	1	(1) Drum failure	:00	:44	0
6/24/58	20:00	:00	0		:00	:38	0
6/25/58	18:32	1:28	1	(1) Drum failure	:00	:38	0
6/26/58	19:34	:26	1	(1) Drum failure	:00	:53	0
6/27/58	20:00	:00	0		:00	:47	0
6/30/58	20:00	:00	0		:00	:49	0
TOTALS	410:41	9:04	8		:15	21:08	1

Personnel

The personnel associated with the department, and, hence, the contributors to this report are:

Avizienis, Algirdas A., University Fellow (through June 15)
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Bivins, Robert L., AEC Fellow (through June 15)
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UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM

PART II - MATHEMATICAL METHODS

PART III - ILLIAC USE AND OPERATION -
GENERAL LABORATORY INFORMATION

July, 1958

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part through Contract No. AT(11-1)-415 of the Atomic Energy Commission. The contract is supported jointly by the Atomic Energy Commission and the Office of Naval Research. In addition, this work is supported through Contracts N6ori-07130 and Nonr-1834(15), both from the Office of Naval Research.

The University of Toronto is participating in this work through staff members of its Computation Centre.

1. Shifting Register Test Unit

The logical design of a shifting register test unit was completed during the month. The major components of the test unit are:

a) an auxiliary counter with three binary digits which sequences in pseudo-random fashion through the six states 0, 1, 2, 5, 6, 7,

b) a fast shift counter with separate borrow storage; the counter is initially set to the number of shifts to be performed and counts downward to zero; a zero-recognition circuit is provided,

c) an eight binary-digit double rank shifting register with gates,

d) an eight binary-digit toggle switch register, and

e) a speed independent control.

In operation, the shifting register is manually set to agree with the toggle switch register. A number n is gated from the auxiliary counter to the shift counter and n left shifts are executed. The number n is again gated to the shift counter and n right shifts are executed. The shifting register contents are then checked against the toggle switches and a new value of n is determined by a count in the auxiliary counter.

(G. Metze and W. Poppelbaum)

2. Basic Circuits

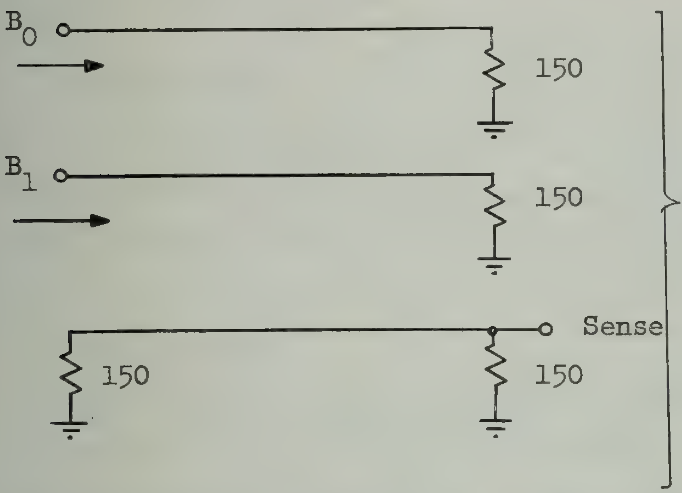
The use of signal level restoration in each logical circuit was studied and a set of circuits designed. A report, entitled "A Set of Basic Circuits",

describing these circuits is in preparation.

(G. Leichner)

3. Core Storage

Transmission Line Tests. Transmission line tests on the B and sense wire arrangement were made, using 1,000 cores. It was found that the delays were short enough with only 1,000 cores to make a large scale prediction very difficult. It appears that for the most desirable type of matching, from driver considerations, there will be some reflected component of current in the bit cores. A much larger scale test is planned to determine if the effect produced is detrimental.



(G. Leichner)

Switch Core Measurements. Several measurements have been made to obtain design data for the word-arrangement memory described in Report 80. One of the measurements was for the purpose of determining the best available switch core on the basis of switching flux and disturb output, i.e., squareness. The disturb test was made with 2 amp turn bias and a 2 amp turn pulse applied with 0.5 Ω load while the switching flux test was made with the drive field adjusted to produce complete switching in 0.2 μs into a 91 Ω load with cores at 30° C. On the basis of this data it appears that the most suitable switch core materials of the eight types tested are MF3876 (General Ceramics) and XF3875 (RCA), although S4 and S5 are somewhat squarer but have disproportionately higher coercive force.

Some measurements of the temperature rise and change in disturb output with temperature were also made. These tests showed that a maximum temperature rise of about 70° C in free air could be expected for switch cores driven as they

would be in actual service and that a 33% increase in disturb current could be expected for this temperature rise.

These tests also indicated that it may be desirable to add 1.5 to 2 ohms in series with the word lines in order to decrease the switch-core disturb currents. The tolerable limits of this disturb current have not yet been accurately determined, however, because the limits are closely correlated with the regulation which can be maintained on the rewrite currents (B-currents) which are, themselves, dependent on the mismatch and mutual-coupling pickups. To measure the latter currents accurately, at least a one-half length B-line must be used and such a length is not presently available.

(S. Ray)

4. Diode Testing

For Qutronics Q5-250 and Q10-600 diodes the temperature coefficient of forward voltage drop at 10 ma was measured and found to be 1.25 ± 0.15 millivolts per $^\circ$ C in the vicinity of 25° C. The coefficient given includes meter error.

(J. Sullivan)

5. Arithmetic Unit

Quotient Digit Frequencies. A method for determining the relative frequencies of quotient digits was devised during the month. For the radix four division method described in Report 82, "A New Class of Digital Division Methods", the frequencies were found to be:

$$\begin{array}{lllll} q_j = 0 & \qquad & 1/4 & = & 0.25 \\ q_j = 1 & & 19/39 & = & 0.487 \\ q_j = 2 & & 41/156 & = & 0.263 \quad , \end{array}$$

with positive and negative digits of any one value equally likely. In the "don't-care" selection range (i.e., $\frac{1}{3}|d| < 4|x_j| < \frac{2}{3}|d|$), it was assumed that the probability of selecting $q_j = 0$ dropped linearly from 1 for $\frac{1}{3}|d| = 4|x_j|$ to 0 for $4|x_j| = \frac{2}{3}|d|$ and that the probability of selecting $q_j = 1$ rose linearly from 0 to 1 in the same range. A similar assumption was made for the selection range $1\frac{1}{3}|d| < 4|x_j| < 1\frac{2}{3}|d|$ for probabilities of selection of $q_j = 1$ and $q_j = 2$.

As a check of the method, the division inverse to the Report 80 radix 4 multiplication was determined. Equal digit frequencies of 1/3 were found for both the multiplication and the corresponding division inverse.

(J. Robertson)

Equations for Radix 4 Arithmetic. Many of the design equations for the arithmetic unit in Report 80 are expressed in terms of binary operation. During the month, equations for radix 4 operation were derived, and more attention was given to the details of mechanization of division. A File Number, entitled "An Introduction to the Logical Design of the Non-Standard Circuits for Multiplication and Division", denoting the results is in preparation.

(J. Shelly)

6. Input-Output and Auxiliary Storage

During the month of July the Ampex manufacturing facilities and development laboratories in Redwood City, California, were visited. Recent developments in the art of magnetic recording were discussed with Dr. A. S. Hoagland, IBM Research Laboratory, San Jose, California.

The maximum packing density consistent with good reliability is an important consideration in the application of digital magnetic tape recorders to our input/output system for the new computer. Our opinion that tape "skew" was a major limitation in published tape recorder performance specifications was confirmed during the above visits. Tape skew can be considered as including two parts, static skew and dynamic skew. Static skew effects, i.e., those due to head alignment errors, tape guide misalignment, gap scatter, etc., can be largely eliminated by recording and playing back on the same unit. If interchangability of reels is not a requirement, this alone might allow the packing density to be increased from about 300 pulses/inch to about 500 pulses/inch.

The experience of others has been that, while timing errors due to dynamic skew may not vary linearly across the tape, such errors are considerably less in adjacent channels than in those some distance away. This indicates that the use of several clock channels, along with a resynchronization buffer, would be a reasonable method for further reducing the skew-imposed limitations on packing density.

Tape quality appears to be the major limitation in considering pulse packing densities of the order of 1,000 bits/inch. Given tape of the necessary high quality, currently available heads are capable of recording and playing back at such densities. Fortunately, it seems likely that the quality of commercially-available tape will continue to improve; the possibility of making practical application of such high densities within the next two or three years should be seriously considered.

The Ampex engineers recommended that, in order to operate at densities in excess of 500 or 600 pulses/inch, some sort of peak detection be used in the playback circuits; such peak detection is not a part of the standard Ampex circuit package. In addition, they recommended use of some sort of logical reading system, such as that proposed by Hoagland* and used on the Illiac drum.

The Ampex FR-300 system uses 16 channels on 1-inch tape, moving at 150 inches/second. Since at least one channel will probably be reserved for parity checking, the use of more than one clock track seriously limits the number of available data channels. Some sort of self-clocking might be advantageous. For instance, if three clock tracks were used there would be 12 bits of data per row across the tape, and 5 bit rows must pass the head each time a word is written. Using the same packing density and considering the same skew effects, it would be possible to record a word in just four rows if the following procedure were used: divide the fifteen available channels into five groups of three channels each; devise a code such that at least one channel in each group of three must always a "1"; this throws away one of eight possible states for each group of three channels is now just slightly over fourteen bits; the first "1" in each group serves as the gate signal for that group. A 53-bit word can be recorded in four rows, giving a 20% increase in word rate.

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* A. S. Hoagland, "A Logical Reading System for Nonreturn-to-Zero Magnetic Recording", Trans. IRE, Vol. EC 4, p. 93.

PART II

MATHEMATICAL METHODS

1. Iterative Methods for Solving Systems of Linear Equations

(Supported in part by the Office of Naval Research under Contract N6ori-07130)

A bound has been found for the difference between the numerical approximants to the solution of the system of equations Ax = y and the true solutions. That is, a bound has been obtained for the magnitude of the vector $\bar{\xi}^{k} - x$, where $\bar{\xi}^{k}$ is the digitalized k^{th} approximant to the solution obtained by using the method described in the April 1958 Technical Progress Report of the Digital Computer Laboratory for matrices having Young's property A.

Numerical experiments are being undertaken to verify the goodness of these bounds.

(G. Golub)

2. Hydrodynamic Flows with Shocks

(Supported in part by the National Science Foundation under Grant G2794.)

Various methods of integrating the equations of hydrodynamics by explicitly following the motion of discontinuities, when they occur, are being investigated. The methods are being studied in detail for one-dimensional problems, but may readily be extended to higher dimensional ones.

(C. Farrington)

3. Relativistic Hydrodynamics

(Supported in part by the National Science Foundation under Grant G2794.)

A report, entitled "Static Spherically Symmetric Space-Times Containing a Relativistic Gas", has been prepared. In this report a derivation is given of the system of ordinary differential equations and the boundary conditions that must be satisfied by the gravitational potentials, the pressure and density of a spherically symmetric distribution of a perfect gas obeying the relativistic caloric equation of state.

These equations are being integrated by use of the Illiac.

(A. Taub)

PART III

ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

Machine Use

During July, specifications were presented for 20 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1180. Numbers followed by T are for theses.

1180 T Electrical Engineering. Analysis of Networks. An analysis of 4-terminal active networks is made to compute short circuit admittance parameters for sinusoidal distributions.

1181 T Mining and Metallurgical Engineering. Low Temperature Specific Heat Calculation. Sets of experimental data for different temperatures are simultaneously reduced to find the least squares value of specific heat.

1182 Astronomy. Radio-Astronomy Antennas. Proposed antennas for future radio-astronomy work will be evaluated.

1183 T Chemistry. Potential Energy Surface Functions. Suitable analytic functions which qualitatively describe the potential energy surfaces of certain activated complexes will be calculated and plotted so as to satisfy experimentally-determined boundary conditions. The exact form of the function will probably be altered as the calculation proceeds.

1184 State Water Survey. Correlation Analysis of Stream Flow and Water Quality. The quantitative measure of the association between several chemical constituents of water and the degree of association between the chemical quality of stream water and the rate of flow will be determined statistically for several Illinois streams.

1185 T Structural Research. Analysis of Continuous Flat Plate. First a single panel with simplified boundary conditions will be solved by a very fine finite difference network involving 400 simultaneous equations. The problem will be cut into parts, each of 80 simultaneous equations, whose solutions will be subsequently joined together.

Using the solution of a single panel, the solution of a continuous plate will be carried out by a "moment and shear distribution" procedure which corrects for the boundary forces by successive approximation. The programming of this procedure to give convergence to a stable set of values with desired degree of precision will be the main purpose of this problem.

1186 T Psychology. The Relationship between IQ and Diversity of Meaning Space. Extreme intelligence groups are being compared on several measures derived from their ratings of a set of heterogeneous concepts on 20 semantic differential scales. Their generalized variance, average variance per scale, percent of variance on first centroid factor, number of factors necessary to account for 75% of the standardized variance, etc., are to be compared in order to determine whether these variables are related to intelligence.

1187 Institute of Communications Research. The Phonemic Structure of Amoy Chinese. Correlational techniques, factor analysis, and analytic rotational procedures are to be applied to the phonemes in Amoy Chinese in an attempt to meaningfully classify the phonemes.

1188 Psychology. Parent and Child Behavior. Parents' perception of each other and of their child and ratings of each child by two teachers gives 72 variable rating scales, a child behavior scale and a parent behavior scale. These will be analyzed statistically to provide answers to: (1) the technical adequacy of the rating devices used in the study, (2) the relationship of interparental behavior to perceived child behavior, (3) the relationship of interparental behavior to teacher evaluation of child behavior, (4) the relationship of parental perception of child behavior to teacher perception of child behavior.

1189 Mechanical Engineering. Calculation of Turbulent and Laminar Compressible Boundary Layers with Arbitrary Pressure Gradient. A code is being developed to calculate both turbulent and laminar compressible boundary layer built up along a solid surface with arbitrary pressure gradient. Integrals of the types

$$f(\xi) = c_1 + \int_{X_1/D}^{X/D} M^{3+\frac{2}{n}} \left(\frac{T}{T_o} \right)^{4-\frac{1}{n}} d\left(\frac{X}{D}\right), \quad \frac{T}{T_o} \left[M(X) \right]$$

and $$f(L) = c_2 + \frac{1}{\xi} \int_{\xi_1}^{\xi} \left[b(\xi) - \ln \frac{M(\xi)}{M_1} \right] d\xi$$

have to be calculated. As the range of numbers involved is very wide (between 10^8 and 10^{-8}), floating decimal routines have to be used.

1190 T Economics. A Statistical Analysis of the Demand for Coal for Use in Residential Space Heating. The demand for coal is thought to depend upon the relative price of coal with respect to the price of gas, the coldness of the winter measured in degree days, the number of miles of gas mains in the United States each year, and the income per household in the region under consideration. Coefficients in a demand equation will be estimated statistically.

1191 Psychology. Factor Analysis of Follow-up Data in a University Department of Education. About 100 students have been rated on about 100 traits; an intercorrelation routine, centroid analysis, and quartimax rotations will be used to analyze this data.

1192 Computer. Incubus. The Monte Carlo method will be used to compute the configuration statistics of an idealized model of a ferromagnet. This model is an extension of the Ising model, taking into account second and third neighbor interactions, as well as interactions with an external magnetic field. The program will be used to test various Monte Carlo schemes in an attempt to find those which give the fastest convergence rates and are therefore most economical of computing time.

1193 Electrical Engineering. Optimum Design of the Equi-angular Spiral Antenna. The lowest frequency of operation of an equi-angular spiral antenna depends on the diameter or size of cable and the rate of spiraling. A transcendental equation relating these will be solved by Newton's method.

1194 T Structural Research. Distribution of Loads in Railway Bridges. The distribution of static train loads through the floor systems of steel railroad bridges will be solved by first using Newmark's distribution procedure to obtain the load on each member and then using anisotropic plate theory to compute the stresses and deflections at different points in the plate. After the determination of stresses due to each load, the total stresses due to a series of loads would be obtained by superposition.

1195 T Structural Research. Approximations to the natural frequencies and nodes of vibrations of continuous spherical shells may be obtained from the solution of the matrix equation $|A - \lambda B| = 0$, where A is the stiffness matrix of the shell and B represents the maximum distribution. These results may be used in calculating the response of spherical shell structures subjected to a dynamic loading.

1196 Electrical Engineering. A Study of Direction of Arrival of Radio Signals. This program is designed to take measured information on the direction of arrival of radio signals to compute the mean, the standard deviation and cube root of the third moment about the mean for this data. It also plots or tabulates the distribution function for the data.

1197 Physics. Meissner Effect of Superconductivity. The problem is to calculate a double integral

$$\int d\varepsilon \int d\varepsilon' \, f(\zeta, \varepsilon') \cos \alpha(\varsigma - \varepsilon')$$

for about 10 values of α. This is done by first summing f along lines y - x = constant, storing these values, and then performing the second integration.

In order to assess scaling factors for the integration in a previous run f(a + x, -a + x) is to be plotted on the cathode ray tube as functions of x for about 5 values of a.

1198 T Psychology. Some Personality Correlates of an Absolute Judgement Task. A series of personality variables is to be correlated with differences in performance on an absolute judgement task and a color perception test. The factor structures of the correlation matrices are to be compared for two samples with and without aptitude scores. It is expected that the largest of the rotated factors should correlate highly with accuracy of judgement and negatively with various measures of neuroticism.

1199 Computer. Obtaining Best Chebyshev Polynomial Approximation. A generalized curve-fitting routine to give the optimum polynomial approximation to a function in the Chebyshev sense will use the method of Stiefel and the double precision floating point multiplication routine.

Table 1 shows the distribution of machine time for the month of July.

TABLE I

	Hrs:Min
Regular Maintenance	14:11
Unscheduled Maintenance	2:15
Drum Engineering	40:07
Leapfrog	35:26
R.A.R.	7:49
Wasted	:01
Use by Departments	
Computer	30:53
Physics	20:58
Control Systems Laboratory	95:22
Structural Research	52:32
Struct. Res. (AF 464)	9:39
Theor. and Appl. Mech. (ORD 593 IC)	1:41
Psychology	47:27
Psychology (USPH 1733)	3:08
Elect. Eng.	18:27
Elect. Eng. (Boeing)	2:35
Elect. Eng. (AF 3220)	:07
Elect. Eng. (SC 74898)	:11
Chemistry	60:52
Agriculture	4:23
Mech. Eng. (ORD 1980)	:03
Inst. of Com. Res.	6:39
Inst. of Com. Res. (9067C)	6:50
Economics	20:38
College of Medicine	3:50
Min. and Met. Eng. (AF3789)	:14
Elect. Eng. (Nonr 1834)	1:07
State Water Survey	1:47
Michigan State U. (Economics)	2:47
Classes	23:04
Demonstrations	:51
Miscellaneous	29:31
	545:25

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7 a.m. and 11 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 11 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive, from an error standpoint, to look at the periods between 11 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between 11 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. During the 5:30-6:30 period (when the machine is checked) if no errors are found, the time is given to the "running" column. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to esti ate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for July.

TABLE III

Reader	6
Punch	1
Memory	1
Drum	6
Scope	1
Total	15

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUP-TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
7/1/58	19:31	:29	2	(1) Reader "G" caused an error (2) Drum failure	:00	:53	0
7/2/58	20:00	:00	0		:00	:54	0
7/3/58	20:00	:00	0		:00	:47	0
7/7/58	19:55	:05	1	(1) Drum failure	:00	:31	0
7/8/58	20:00	:00	0		:00	:39	0
7/9/58	19:54	:06	1	(1) Punch "3" failing	:00	:40	0
7/10/58	19:19	:41	3	(1) Reader "G" failing to read correctly (2) Scope causing trouble (3) Drum failure	:00	5:50	0
7/11/58	20:00	:00	0		:00	:41	0
7/14/58	20:00	:00	0		:00	:38	0
7/15/58	19:57	:03	1	(1) Reader "G" fails to read correctly	:00	:42	0
7/16/58	20:00	:00	0		:00	:40	0
7/17/58	19:34	:26	1	(1) Memory error	:00	1:03	0
7/18/58	20:00	:00	0		:00	:54	0
7/21/58	20:00	:00	0		:00	:43	0
7/22/58	20:00	:00	0		:00	:40	0
7/23/58	19:12	:48	2	(1) Drum failure (2) Reader "G" failed	:00	:40	0
7/24/58	18:56	1:04	1	(1) Drum failure	:00	:20	0
7/25/58	19:39	:21	2	(1) Drum failure (2) Reader "G" failed	:00	:39	0
7/28/58	20:00	:00	0		:00	:39	0
7/29/58	20:00	:00	0		:00	:40	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
7/30/58	19:59	:01	1	(1) Reader Error "G"	:00	:33	0
7/31/58	20:00	:00	0		:00	:39	0
TOTALS	435:56	4:04	15		:00	20:25	0

Personnel

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Reports

Report No. 83, "Flow-Gating", by W. J. Poppelbaum, July, 1958

Report No. 84, "On the Existence of Non-Static Plane Symmetric Space-Times", by S. Patnaik, July, 1958

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TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM
PART II - MATHEMATICAL METHODS
PART III - SWITCHING THEORY
PART IV - ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

August, 1958

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part through Contract No. AT(11-1)-415 of the Atomic Energy Commission. The contract is supported jointly by the Atomic Energy Commission and the Office of Naval Research. In addition, this work is supported through Contracts N6ori-07130 and Nonr-1834(15), both from the Office of Naval Research

The University of Toronto is participating in this work through the staff members of its Computation Centre.

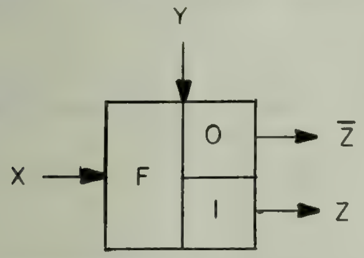
1. Shifting Register Test Unit

Detailed circuit design of the shifting register test unit was completed during the month. Flipflop and gate packages were constructed and checked, and construction of control and gate driver packages was begun.

(H. Lopeman and shop personnel)

2. Basic Circuits

In August two different designs were evolved for the F-element. The F-element is a two-input memory element defined by Table I.



(proposed symbol for an F-element)

TABLE I

X	Y	Z
0	0	LAST STATE
1	0	LAST STATE
0	1	0
1	1	1

The two methods of approach are described below.

In the first method of approach, a Schmitt trigger type of flipflop is preceded by an AND gate and an OR gate controlled by the gating signal y. These gates receive their signals from a switching preamplifier and deliver their output to the input of the flipflop via two setting diodes, D_1 and D_2.

Figure 1 shows a different approach to the design of an F-element. Here, the memory is obtained by feeding back a signal from a complex of two difference amplifiers (T_1 and T_4, and, T_2 and T_5) and a switching amplifier, T_3, into one of the difference amplifiers, logic being performed in the collectors.

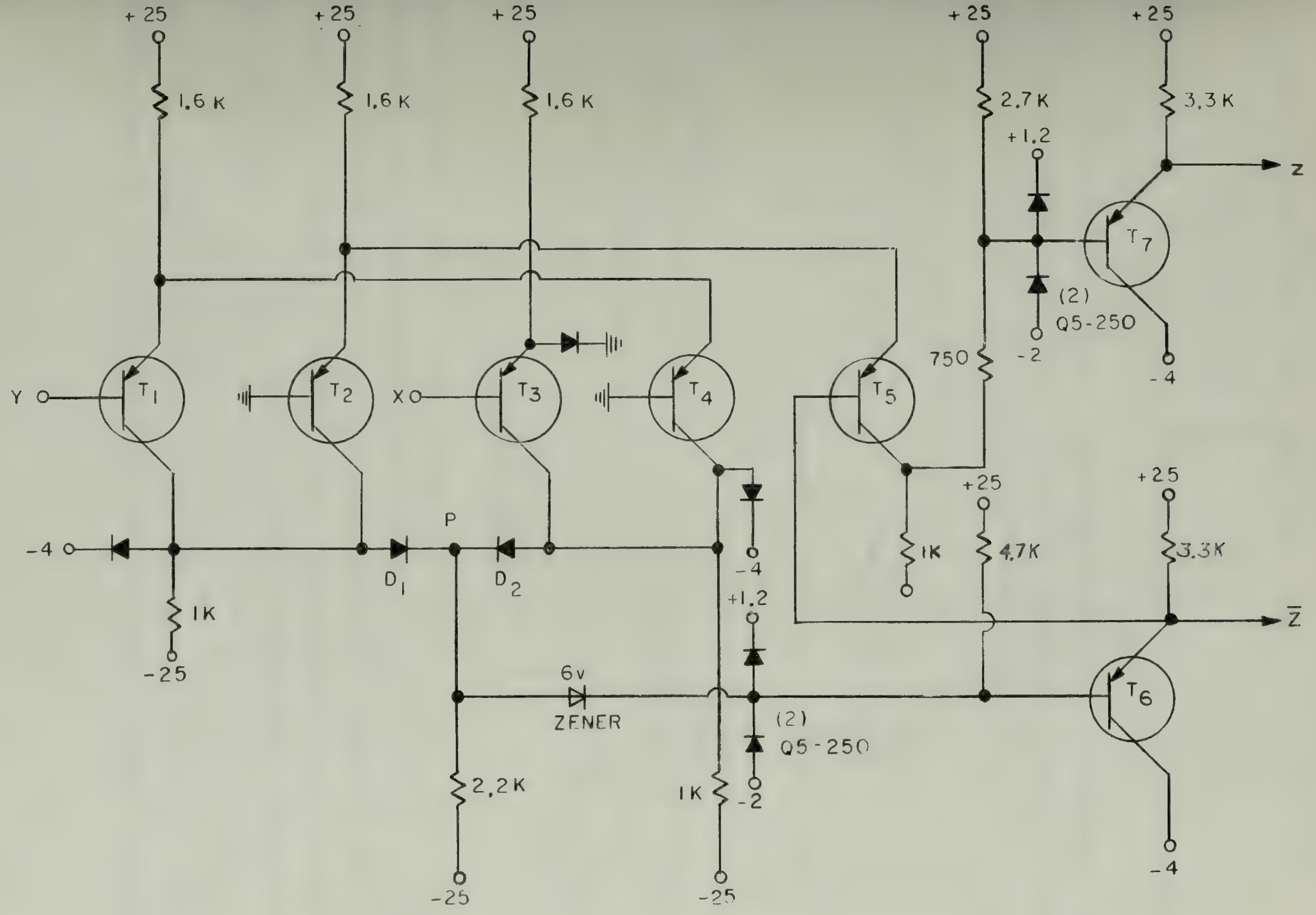


Figure 1

F-ELEMENT

Note that D_1 and D_2 form an OR circuit which only responds when T_1 and T_2 or T_3 and T_4 are conducting. This means that at point p we have

$$\bar{y}\,\bar{z} \vee \bar{\bar{x}}\,y = \bar{z}$$

which implies $z = x$ when $y = 1$ (gating in). If $y = 0$, the internal feedback holds the circuit in its last state.

It is proposed to examine speeds and waveforms in an F-element tester according to Figure 2. The logic is such that a free-running logical oscillator is formed with the gates of the F-elements opening and closing at each cycle.

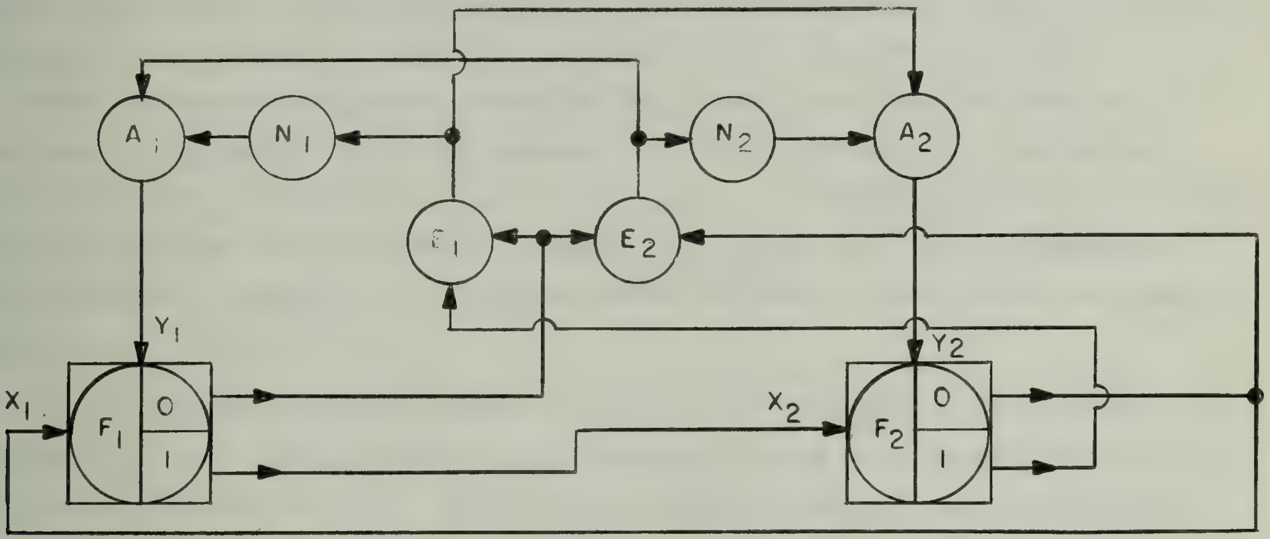


Figure 2
F-ELEMENT TESTER

This can be seen as follows. Leave out NOT circuits, N_1 and N_2 (which are only inserted to insure non-overlapping gating signals, y_1 and y_2). Then, y_1 is made a 1 (this copies the F_2-state into F_1 with an inversion) whenever F_1 and F_2 agree. Similarly, y_2 is made a 1 (this copies the F_1 state directly into F_2) whenever F_1 and F_2 disagree. Visibly, this process makes the F-elements disagree whenever they agree, and vice versa. An oscillation sets in. It should be remarked that N_1 is a part of equivalence circuit E_1 and N_2 a part of E_2 so that the logic outside of the F-elements does not produce more than one collector delay. Since both F-elements have two collector delays, the time for "outside logic" is absorbed

in the operation times of the F-elements, and the latter can be directly measured.

(N. Johnson and N. Wiseman)

3. Core Storage

Detailed specifications for a single core plane were prepared and submitted to manufacturers for bids.

4. Over-all Design

A frequent occurrence, especially in floating point arithmetic, is that a B-line is used by arithmetic control and not by advanced control. In order that advanced control should not be made to wait unnecessarily in such a situation, an indicator is provided for each B-line, which is set by advanced control, and later reset by arithmetic control when the B-line has been used arithmetically. In the case of B_4, which holds the exponent of the floating point accumulator, a 2-bit counter K_4 is provided similar to K_z and K_y. Advanced control is prevented from using a B-line whose indicator is set, or B_4 if $K_4 \neq 0$, or from passing a further arithmetic reference to a B-line whose indicator is set, or an arithmetic reference to B_4 if $K_4 = 3$.

In the case of short loops of instructions held entirely in O_1 and O_2, it is possible that advanced control can process a short loop twice before arithmetic control enters the loop. In this case advanced control has executed one jump instruction which arithmetic control has not executed. Therefore, arithmetic control is permitted to pass advanced control whenever it is one jump behind, and advanced control is always permitted to pass arithmetic control. This simplifies the interlocks between the two order counters.

Jump instructions inside of O_1 O_2 have been extended to arithmetic-conditional jumps as well as B-conditional jumps. Such a jump is to any control group in the current word or the immediately preceding word, even if the latter is not in O_1 O_2. In that case it will be read in automatically by advanced control. This facility was dictated by the program interruption system.

(D. B. Gillies)

5. Tolerance Analysis

General Tolerance Analysis Program 1206 was written during the month. This program performs a d.c. tolerance analysis on any specified circuit (smaller than a certain maximum size). The user prepares a data tape specifying the circuit configuration, component values and tolerances. The program is to be used in the investigation of experimental circuits.

(G. Leichner)

PART II

MATHEMATICAL METHODS

1. Hydrodynamic Flows with Shocks (Supported in part by the National Science Foundation under Grant G2794.)

The Rankine-Hugoniot equations for one-dimensional problems constitute three conditions on the seven variables, ρ_1, u_1, U_1, ρ_2, u_2, U_2, V, where ρ_1, u_1, U_1 are the density, fluid velocity and internal energy immediately ahead of the shock; ρ_2, u_2, U_2 are those immediately behind the shock; and V is the shock velocity. If ρ_1, u_1 and U_1 are assumed known, another condition must be imposed to determine the other four variables. One condition which can be used is characteristic equation

$$\frac{\partial p}{\partial t} + (u + a)\frac{\partial p}{\partial x} + \rho a \quad \frac{\partial u}{\partial t} + (u + a)\frac{\partial u}{\partial x} = 0 \qquad (1)$$

where $p = p(\rho,U)$ is the pressure and $a = \frac{\partial p}{\partial \rho}$ is the sound velocity. $p(\rho,U)$ is assumed to be a known function. The suitability of this condition for the numerical integration of initial value problems is being investigated.

When equation (1) is replaced by an appropriate difference equation, one obtains a system of four nonlinear equations for ρ_2, u_2, U_2 and V. By looking at the determinant of the matrix of partial derivatives it was found that these equations determine a unique solution for any finite value of the shock strength $\eta - 1 = \frac{(\rho_2 - \rho_1)}{\rho_1}$. However, the determinant has a simple zero for $\eta = 1$; i.e., for infinitely weak shocks.

When the equations for ρ_2, u_2, U_2 and V are written as

$$\rho_2(u_2 - V) - \rho_1(u_1 - V) = 0$$

$$\rho_2 u_2(u_2 - V) + p_2 - \left[\rho_1 u_1(u_1 - V) + p_1\right] = 0$$

$$\rho_2 \Sigma_2(u_2 - V) + p_2 u_2 - \left[\rho_1 \Sigma_1(u_1 - V) + p_1 u_1\right] = 0$$

$$p(\rho_2, U_2) - p_A + \rho_A a_A(u_2 - u_A) = 0 ,$$

where $\Sigma_i = U_i + \frac{1}{2} u_i^2$ and p_A, ρ_A, a_A, u_A are known, it is found that small changes in the residues lead to large changes in the values of ρ_2, u_2, U_2 and V, so that double precision arithmetic must be used to obtain solutions of these equations to an accuracy of $\pm 2^{-40}$.

(C. Farrington)

2. Relativistic Hydrodynamics (Supported in part by the National Science Foundation under Grant G2794.)

A first draft of a paper, entitled "Static Spherically Symmetric Space-Times Containing A Relativistic Gas", was written. It is the purpose of this paper to discuss the derivations and the numerical solutions of the Einstein field equations for the metric tensor associated with a spherically symmetric distribution of matter consisting of a relativistic gas. The notions of gravitational mass, total energy and potential energy are examined.

(A. Taub)

3. Monte Carlo Methods (Supported in part by the Office of Naval Research under Contract N6ori-07130)

Two programs, known as INCUBUS and INTERLINCH have been completed and are being checked. The INCUBUS program computes order parameters for a simple cubic Ising lattice in a magnetic field. The INTERLINCH program computes the mean displacements of atoms in a linear chain, with fixed end points, when an extra atom is inserted in the middle of the chain. The latter program was written to test the feasibility of doing the calculation in three dimensions. Both of these programs are described in File No. 254, "Two Programs for Studying Certain Problems in Statistical Mechanics by the Monte Carlo Method".

(L. Fosdick)

PART III

SWITCHING THEORY

(Supported in part by the Office of Naval Research under Contract N6ori-07130)

An investigation was made of the properties of circuits which are semi-modular and yet contain arbitrary delays at the inputs to all logical elements. Such circuits were shown to be capable of performing only limited types of operations, described as one-periodic. Most of the more complex operations performed by computers, such as counting and addition, do not fall into this category, and for this reason a semi-modular computer could not be constructed under the assumption that arbitrary delays appear at the inputs to all elements. Specifically, it was shown that whenever a signal at one point in a circuit is required to undergo two or more changes between successive changes at a second point, then some input to an element in the circuit is not allowed to possess an arbitrary delay.

(J. Shelly)

PART IV

ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

Machine Use

During August, specifications were presented for seven new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1200. Numbers followed by T are for theses.

1200 T Chemistry. Nuclear Magnetic Resonance in Chemical Equilibrium. The Illiac will be used to make least squares set of nuclear magnetic resonance shifts to various empirical equations.

1201 Psychology. Personality and Pain Thresholds. A personality questionnaire has been administered to a group of subjects. Their pain threshold scores, aspiration, and other scores were also obtained. The aim is to obtain intercorrelation between the two types of scores. This includes 142 variables. Library Routine K-8 will be used.

1202 T Chemistry. Spin Matrix. This problem is an extension of No. 997 T (Solution of 3 or 4 Spin Systems). The proposed program will be designed to calculate spin matrices from general rules for such matrices and will form matrices for up-to-12-spin systems. At least in its initial form, however, the program will actually solve the matrices (using M-18) and compute the spectra of systems of 6 spins or less.

1203 Physics. Critical Temperature of Superconductors. Experimental evidence has indicated that the relatively simple Bardeen-Cooper-Schrieffer theory of superconductivity does not hold in certain superconducting materials. It is desired to calculate the "energy gap" as a function of temperature and especially to find the critical temperature above which the "energy gap" vanishes, using the better approximation of the Bogolyabov theory of superconductivity in order to

compare it with experiment. In this latter theory the following non-linear integral equation arises:

$$C(\xi,T) = N(0)V \int_0^\infty \frac{d\xi' \, h\bar{\omega} \, C(\xi',T)}{\sqrt{C^2(\xi',T) + \xi'^2}} \left[\frac{1 - \dfrac{1}{1 + e^{\frac{\sqrt{C^2(0,T) + \xi'^2}}{kT}}}}{h\bar{\omega} + \sqrt{C^2(0,T) + \xi^2} + \sqrt{C^2(0,T) + \xi'^2}} - \frac{\dfrac{1}{1 + e^{\frac{\sqrt{C^2(0,T) + \xi'^2}}{kT}}}}{h\bar{\omega} + \sqrt{C^2(0,T) + {}^2} - \sqrt{C^2(0,T) + \xi'^2}} \right]$$

Here $N(0)V$ and $h\bar{\omega}$ are parameters characterizing the superconducting material, and T is the absolute temperature. $2C(0,T)$ is the "energy gap". By changes of variables the integral can be reduced to integrals having finite limits. For each set of values of $N(0)V$ and $\frac{kT}{h\bar{\omega}}$ the function $\frac{C(\xi,T)}{h\bar{\omega}}$ will be found by iteration from a trial solution, stopping when successive iterations at each mesh point agree within a fixed percentage. The critical temperature for each value of $N(0)V$ will be found by extrapolation from successive approximations from below. The integrations will be evaluated by Simpson's Rule, using the library routine for tabulated integrands.

1204 T Psychology. Changes in Learning Over Time. Four hundred and sixty high school students were given 9 achievement tests, and these tests were repeated to the same group four times on four consecutive years. In addition, the students were given 30 aptitude tests. A correlation matrix for the 66 variables was calculated on an IBM 650 machine. It is proposed to extract factors from the 66-variable matrix and to study the changes within factors over time.

1205 T Civil Engineering. Contact Stresses in Lugs. The Illiac will be used to examine the effect of changes in the parameters and variables in the stress-strain relations.

1206 Computer. General Tolerance Analysis. The program reads a data tape which describes the manner in which a circuit is connected and compiles a routine for analyzing it. Transistors, diodes, zener diodes, resistors, and any components describable by tables of values or a formula may be included. The analysis routine solves for all unknown node voltages and all branch currents by a multidimensional Newton iteration method. Circuits with less than 30 branches, 13 unknown nodes, and 10 fixed nodes may be handled. The program brings portions of data and program from the drum as required during the process. All computations are performed in floating point.

Table 1 shows the distribution of machine time for the month of August.

TABLE I

	Hrs:Min
Regular Maintenance	20:00
Unscheduled Maintenance	6:09
Drum Engineering	38:47
Leapfrog	35:56
R.A.R.	9:44
Wasted	9:01
Use by Departments	
Computer	19:27
Physics	20:25
Control Systems Laboratory	148:41
Structural Research	23:33
Struct. Res. (AF 464)	5:50
Theor. and Appl. Mech. (ORD 593 IC)	1:19
Psychology	76:14
Elect. Eng.	21:34
Elect. Eng. (SC 74898)	2:50
Chemistry	66:20
Agriculture	8:16
Inst. of Com. Res.	:52
College of Medicine	1:06
Min. and Met. Eng. (AF3789)	:10
State Water Survey	2:51
Classes	8:57
Demonstrations	:30
Miscellaneous	20:36
	549:08

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7 a. m. and 11 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 11 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive, from an error standpoint, to look at the periods between 11 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between 11 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. During the 5:30-6:30 period (when the machine is checked) if no errors are found, the time is given to the "running" column. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for August.

TABLE III

Memory	1
Input-output	3
Drum	17
Reader	4
Punch	2
Control	1
Scope	1
Power failure	1
Unknown	1
	31

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
8/1/58	19:56	:04	1	(1) Drum failure	:00	1:17	0
8/4/58	19:57	:03	1	(1) Drum failure	:00	1:02	0
8/5/58	20:00	:00	0		:00	:44	0
8/6/58	19:58	:02	2	(1) Light on Reader "C" out while Leapfrog on (2) Drum failure	:00	:39	1
8/7/58	20:00	:00	0		:00	:39	0
8/8/58	19:59	:01	1	(1) Punch # 4 failed	:00	:31	0
8/11/58	19:52	:08	1	(1) Memory failure 2^{-14}	:00	:48	1
8/12/58	19:59	:01	1	(1) Scope error	:00	:44	0
8/13/58	18:35	1:25	1	(1) Drum failure	:00	:40	0
8/14/58	18:23	1:37	2	(1) Drum failure (2) Input error	:00	:45	0
8/15/58	20:00	:00	0		:00	:39	0
8/18/58	19:59	:01	1	(1) Drum failure	:00	:40	0
8/19/58	20:00	:00	0		:00	:43	0
8/20/58	10:50	:09	3	(1) Reader "D" made an error (2) University power failure (*) reason for 9:01 in wasted column (3) Reader "D" made an error	*9:01	:21	0
8/21/58	17:55	2:05	2	(1) Reader "D" made an error (2) Drum failure	:00	:50	0
8/22/58	19:56	:04	4	(1) Drum failure (2) Drum failure (3) Drum failure (4) Drum failure	:00	:42	0
8/25/58	19:58	:02	2	(1) Input-output failure (2) Unknown	:00	1:01	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
8/26/58	19:55	:05	5	(1) Punch # 3 erred (2) Drum failure (3) Drum failure (4) Drum failure (5) Drum failure	:00	:39	0
8/27/58	19:09	:51	2	(1) Control error (2) Drum error	:00	:48	0
8/28/58	19:58	:02	2	(1) Input error (2) Drum error	:00	:51	0
8/29/58	20:00	:00	0		:00	:40	0
Totals	404:19	6:40	31		*9:01	15:43	2

Personnel

The personnel associated with the department, and, hence, the contributors to this report are:

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Buenger, George E., Research Assistant
Carter, Clifford E., Electronics Engineer for Illiac
Chow, Yuan S., Research Associate
Clark, Miss Helen B., Secretary
Cummins, Richard L., Research Assistant
Drabik, Edward T., Jr. Laboratory Mechanic (resigned August 29)
Ehrman, John R., Research Assistant (through August 15)
Farrell, Roger H., Research Assistant (through August 15)
Farrington, Carl C., Research Assistant
Fosdick, Lloyd D., Res. Asst. Prof. of Physics
Foster, Merlin J., Computer Operator I
Foulk, Clinton R., 1/2-time Research Assistant
Gillies, Donald B., Res. Asst. Prof. of Appl. Math.
Golub, Gene H., Research Assistant
Gustafson, Ronald A., Jr. Electronics Technician
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Kellner, Miss Katherine E., 3/4-time Research Assistant
Kerkering, Thomas E., Sr. Laboratory Mechanic
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The Department Advisory Committee consists of Professors L. D. Fosdick, D. B. Gillies, D. E. Muller, W. J. Poppelbaum, J. E. Robertson, J. N. Snyder and A. H. Taub.

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TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM
PART II - MATHEMATICAL METHODS
PART III - ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

September 1958

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part through Contract No. AT(11-1)-415 of the Atomic Energy Commission. The contract is supported jointly by the Atomic Energy Commission and the Office of Naval Research. In addition, this work is supported through Contract Nonr-1834(15) from the Office of Naval Research.

The Computation Centre of the University of Toronto and the Rich Electronic Computer Center of the Georgia Institute of Technology are participating in this work through their respective staff members.

1. Shifting Register Test Unit

The frame and plug wiring and control and driver circuits were completed and checked during the month. All units, including power supplies, were assembled, and power was applied on October 1, 1958.

(H. Lopeman and shop personnel)

2. Basic Circuits

In September a majority function circuit, making use of the analog addition of collector currents to form the output, was tested for speed. It turned out that the heavy bumping diode currents involved made the circuit slower than a classical combination of AND and ORs and the project was dropped.

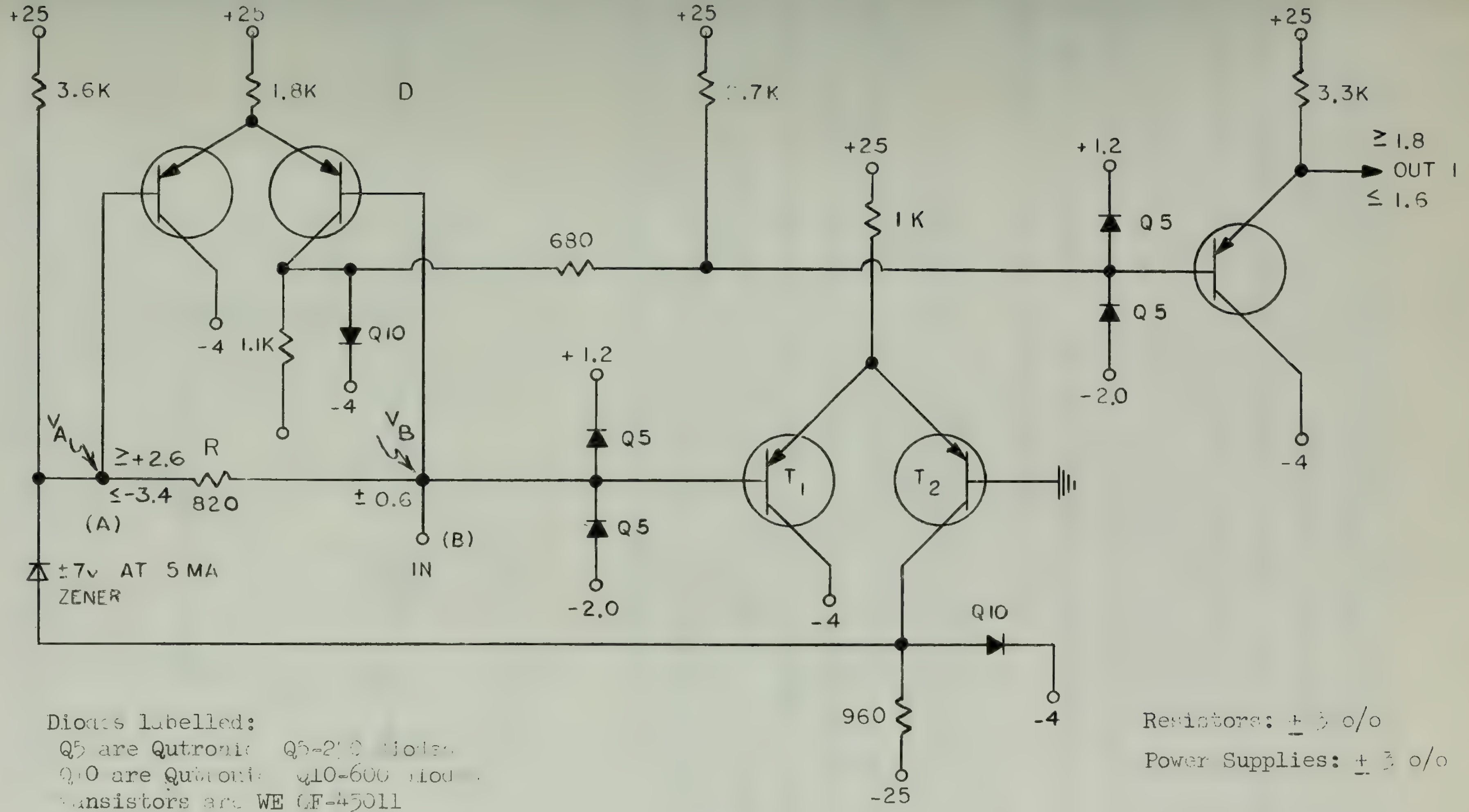
(G. Buenger)

A transistor pulse-tester was built and put into operation. Zener diodes provide the necessary biasses and a relay pulser is used as an input generator. The input network is designed in such a fashion that it simulates the output of a NOT circuit.

(M. Schleifer)

A new design has been found for the so-called last moving point flipflops. It was realized that any direct sensing of the state of the collector of a Schmitt trigger type of flipflop is insufficient to give positive information about the holding properties. It was therefore decided to insert into the collector-to-base feedback loop (see Figure 1) a resistor R and to sense the polarity at its extremities A and B by means of a difference amplifier D.

The operation of this flipflop can be described as follows. Suppose that T_1 is cut off. Then T_2 is on and A is very positive, dragging B against the positive bump.



Diodes labelled:
Q5 are Qutronic Q5-2[illegible]0 diodes
Q10 are Qutronic Q10-600 diodes
Transistors are WE GF-45011

Resistors: ± 5 o/o
Power Supplies: ± 3 o/o

Figure 1

Last Moving Point Flipflop

Obviously $V_A > V_B$. If a negative-going signal is applied at the input B (not necessarily dragging B against the negative bump) at about -0.3V, T_1 will start to conduct, switching T_2 off. During this whole process we still have $V_A > V_B$. Finally, however, point A is going to overtake point B. This happens when the feedback holds A below B. It is seen immediately that this is precisely the condition necessary for the flipflop to hold its new state. It is also seen that at this point the input signal can be safely taken away, for no point between A and the emitter of T_1 could go sufficiently positive (since they are all negative) to switch T_1 off again. The same reasoning shows that the flipflop is also last moving point on the on-to-off transition of T_1.

(W. J. Poppelbaum)

The flipflop was subjected to the following test: a sine-wave oscillator -- with its frequency varied between 20 cps and 25 mcps -- was connected to an AND gate feeding the input of the flipflop via diode D_2. On the negative part of the cycle diode D_1 set the flipflop back. The out-of-phase output of the difference amplifier was connected to the second input of the gate. On the positive part of the cycle the gate was therefore cut off as soon as the flipflop output reacted. In a non-last moving point flipflop this test invariably results in the flipflop falling back to its old state; here the output was a perfect square wave at the frequency of the oscillator. Figure 2 shows the set-up.

(N. H. Johnson)

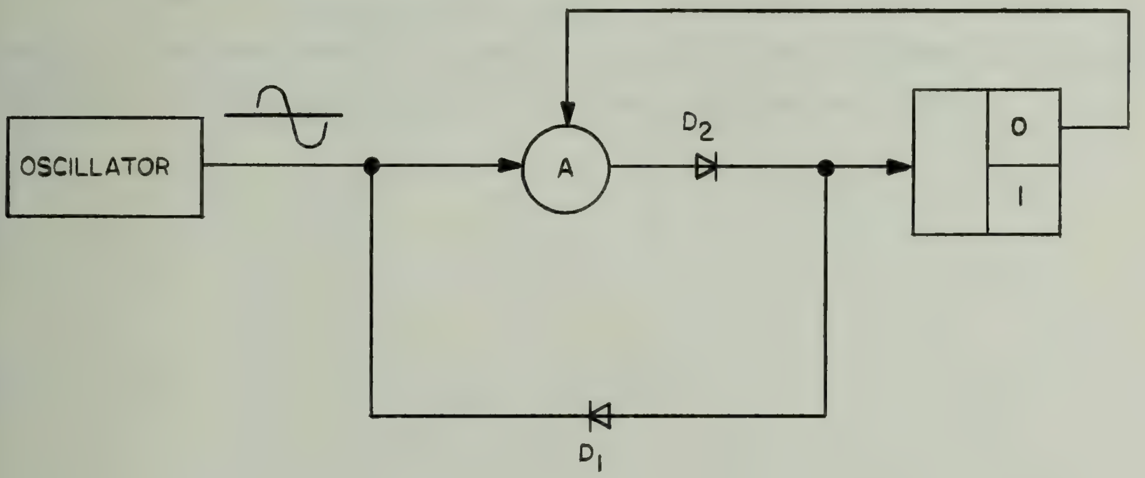


Figure 2. Last Moving Point Flipflop Test Set-up

3. Input-Output and Auxiliary Storage

Chapter 7 of Report 80 was revised to include a discussion of the characteristics of commercially available digital magnetic tape recorders, particularly those characteristics responsible for limiting packing density and data rates to undesirably low values. Some proposed methods for improving data rates beyond those recommended by the manufacturers were discussed. An input-output system was described consisting of several high-speed magnetic tape units (serving as auxiliary memory as well as input-output devices), a secondary tape unit for matching data rates of terminal equipment, paper tape punch and reader (with connections to magnetic tape units and to core memory directly), and a line printer.

Final specifications for purchase of the first magnetic tape unit were written. Characteristics of this tape unit will include: 10-1/2-inch reels, 1-inch tape width, 150 and 20-inches/second tape speed, 16 channels (dual heads for simultaneous recording and monitoring), and 1.5 millisecond start-stop time.

(R. Cummins)

4. Power Supply

It would be desirable to have some regulated power supplies similar to those of drawing M-733 with a voltage range of 0.5 - 2.5 v. D.C. A tentative design has been produced for this range. Final calculations are now awaiting further data on available power transistors.

The two transistorized power supplies which were returned for repair have been received and seem to be working properly. One of these can be modified to serve as the -4v. supply for the shifting register test unit.

(J. Muerle)

PART II

MATHEMATICAL METHODS

1. Iterative Methods for Solving Systems of Linear Equations

(Supported in part by the Office of Naval Research under Contract N6ori-07130)

The effects of round-off errors on the approximants to the solution of a system of linear equations are being investigated. Bounds have been obtained for the error vectors and the residual vectors. The improvement of these bounds is being attempted.

(G. Golub)

2. Determination of Flows Behind Shocks

(Supported in part by the National Science Foundation under Grant G2794)

It has been shown that if a pseudo-stationary shock is normal to a straight wall, and if the flow ahead of this shock is uniform, then if there is no singularity at the intersection of the shock and the wall

$$\left(\frac{d^{2n+1}}{ds^{2n+1}} k\right)_{s=0} = 0 \qquad n = 0, 1, 2, \ldots$$

and the

$$\left(\frac{d^{2n}}{ds^{2n}} k\right)_{s=0}$$

cannot be determined from the boundary conditions at the wall. In these expressions k is the curvature of the shock and s is the arc length along the shock measured from the wall.

If the wall is not straight, then there must be a sinularity in the shock at the wall.

(Y. Chow)

Monte Carlo Methods

(Supported in part by the Office of Naval Research under Contract N6ori-07130)

The INTERLINCH program (cf. File No. 254) has been checked and certain modifications were made on it to reduce the computation time and improve the accuracy. Initial production computations have been made.

Computations with the Monte Crysto Program (cf. Progress Report, Part III, December, 1957) are nearing completion and it is anticipated that the calculations will be concluded next month. The results of this work are being compiled and will be presented in a forthcoming report.

(L. D. Fosdick)

PART III

ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

Machine Use

During September, specifications were presented for nine new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1207. Numbers followed by T are for theses.

1207 Bureau of Educational Research. Hypothetical Test Stratified Reliability. By random processes a set of results, that could have been the outcome of a set of test questions stratified into nine levels of difficulty, are generated. These are then analyzed in several different ways in order to test the analysis methods and the methods of forming corrections to these analyses.

1208 Electrical Engineering. Dielectric Antenna Patterns. The problem is to determine the radiation pattern in a certain plane when a simple dipole antenna is centrally located in a finite dielectric slab. The problem is set up in the form of a Fredholm integral equation, and it is desired to use the iteration method to obtain an approximate solution. Illiac is to be used to obtain numerical values for the first few terms in the iteration series.

1209 T University of Chicago (Psychology). Successive Set Analysis; Schizophrenics. The problem is to factor an 83 variable matrix in order to obtain an orthogonal approximation to simple structure. Inspection of the data seems to indicate a small number of factors (probably less than ten). The matrix entries are proportions (not correlation coefficients), but can be treated identically. The problem requires only standard library programs for solution. (Counseling Service)

1210 University of Chicago (Psychology). Factors of Anxiety and Ego Strength. Seventy-seven subjects were given a series of tests measuring anxiety and ego strength. It is proposed to discover the interrelations among the various test items by means

of a factor analysis. Each of the tests (5 tests were given) will be analyzed separately, and this will be followed by a composite analysis to be determined later.

1211 T Education. Values of HS Homemaking Teachers. A forced choice instrument was given to 262 homemaking teachers to measure value patterns of these teachers. Eight values were included in three different contexts, making 24 distinct measurements for each of the teachers. The purpose of the study is to determine the relations among the value patterns and to determine the relations among the contexts. The statistical procedures will be to calculate a matrix of correlations, to extract principal axes factors, and finally to rotate the factor matrix to orthogonal simple structure.

1212 Computer. Pi. This is a practice problem to compute $\frac{\pi}{4}$ by series methods to be used as an exercise by certain students in Mathematics 385.

1213 State Water Survey. Raindrop-size Analysis. Photographs of raindrops were taken, during thunderstorms, at one-minute intervals by means of radar equipment. From the photographs, the horizontal and vertical diameters of each raindrop were recorded. The Illiac is to be used to:

1. compute the average diameter of each drop. $d = \frac{h + v}{2}$;
2. compute a frequency distribution on raindrop size for each minute's data;
3. compute five totals or factors, such as volume of water, from the frequency distribution. Each total is of the form

$$T_1 = \sum_{i=1}^{i=n} f_i K_i$$

where n = number of intervals in frequency distribution

f_i = any of the frequency cells

K_i = a constant to be applied to f_i .

Illiac output will be the frequency distribution and the five totals. It is estimated that 1-1/2 minutes of Illiac time is needed for each minute's data.

The project encompasses the analysis of 5,000 minutes data over (approximately) a two-year period.

1214 Student Counseling Service. Contribution of Gordon Personality Scale Scores to Prediction of Enrollment, Withdrawal, and Academic Survival at Chicago Undergraduate Division. This study will determine to what extent scores on the Gordon Personal Profile and the Gordon Personal Inventory may be useful in predicting (a) which prospective students are likely to actually enter the university, (b) which students who enter are most likely to withdraw, and (c) which students who complete a semester are most likely to achieve good standing as opposed to being dropped for poor scholarship. Illiac facilities will be used for the computation of (a) seven 27x27 correlation matrices and (b) twenty multiple correlations. Standard library routines are available for all computations.

1215 Mechanical Engineering. Tabulation of Auxiliary Functions Pertinent to Non-Isoenergetic Turbulent Jet-Mixing. In the consideration of non-isoenergetic turbulent jet mixing, the following integrals are derived:

$$\int_{-\infty}^{\eta} \frac{\varphi}{\Lambda - Ca^2 \varphi^2}\, d\eta \,, \quad \int_{-\infty}^{\eta} \frac{\varphi^2}{\Lambda - Ca^2 \varphi^2}\, d\eta \,, \quad \int_{-\infty}^{\eta} \frac{\Lambda \varphi^2}{\Lambda - Ca^2 \varphi^2}\, d\eta \,,$$

where $\varphi = \frac{1}{2}(1 + \operatorname{erf} \eta)$, $\Lambda = A + (1-A)\varphi$. It is intended to tabulate those two parameter (A,Ca) integrals as functions of η or φ. (For A = 1, it has been done on Illiac.) The possible ranges of the parameters are well bracketed by numerical trials.

Table I shows the distribution of machine time for the month of September.

TABLE I

	Hrs:Min	
Regular Maintenance	34:48	
Unscheduled Maintenance	22:56	
Drum Engineering	42:15	
Leapfrog	50:10	
R.A.R.	7:51	
Program Development	:00	
Wasted	:00	
		158:00
Use by Departments		
Computer	23:55	
Physics	13:31	
Control Systems Laboratory	126:36	
Structural Research	32:54	
Struct. Res. (AF 464)	1:41	
Theor. and Appl. Mech. (ORD 593 IC)	3:38	
Psychology	26:51	
Psychology (P.H. 1733)	:13	
Inst. of Com. Res.	:38	
Inst. of Com. Res. (9067C)	:04	
Electrical Engineering	10:29	
Elect. Eng. (SC 74898)	1:39	
Chemistry	57:44	
Agriculture	8:38	
Mech. Eng. (ORD 1980)	:02	
Economics	16:53	
Min. and Met. Eng. (AF 3789)	:05	
College of Medicine	:42	
State Water Survey	3:02	
State Water Survey (SC 75055)	:32	
U. of Chicago (Psychology)	5:30	
Demonstrations	2:26	
Miscellaneous	17:40	
		355:23
Total		513:23

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7 a.m. and 11 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 11 a.m., together with certain irregular periods such as Saturdays and Sundays, are devoted to a heterogenous group of functions, it is more instructive, from an error standpoint, to look at the periods between 11 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between 11 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. During the 5:30-6:30 period (when the machine is checked) if no errors are found, the time is given to the "running" column. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for September.

TABLE III

Control	4
Memory	3
Scope	3
Punch	1
Reader	1
Drum	15
Input-Output	3
	30

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
9/2/58	19:59	:01	1	(1) Scope error	:00	:56	0
9/3/58	19:06	:54	4	(1) Control error (2) Drum error (3) Drum error (4) Drum error	:00	:56	0
9/4/58	19:57	:03	3	(1) Camera will not advance (2) Drum error (3) Drum error	:00	:40	0
9/5/58	19:57	:03	3	(1) Drum error (2) Reader "D" erred (3) Drum error	:00	:40	0
9/8/58	16:43	3:17	3	(1) Leapfrog failed. Input error (2) Drum error (3) Drum error	:00	:50	1
9/9/58	19:58	:02	1	(1) Drum error	:00	:48	0
9/10/58	4:00	16:00	1	(1) Shift sequencing	:00	7:20	0
9/11/58	19:59	:02	2	(1) and (2) See September 10	:00	1:10	0
9/12/58	19:55	:05	4	(1) Drum error (2) Drum error (3) Drum error (4) Drum error	:00	:54	0
9/15/58	19:49	:11	3	(1) Tape broke in-punch #3, Chadbox not emptied caused jam (2) Input error (3) Scope error	:00	1:40	0
9/16/58	20:00	:00	0		:00	1:22	0
9/17/58	19:50	:10	1	(1) Drum error	:00	3:21	0
9/18/58	20:00	:00	0		:00	:47	0
9/19/58	20:00	:00	0		:00	:40	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUP TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
9/22/58	18:02	1:58	1	(1) Input-output error	:00	4:34	0
9/23/58	20:00	:00	0		:00	:49	0
9/24/58	19:45	:15	1	(1) Memory failure pos. 2^{-1}	:00	1:42	1
9/25/58	19:13	:47	2	(1) Memory failure 2^{-30} (2) Memory failure 2^{-30}	:00	1:41	0
9/26/58	20:00	:00	0		:00	:40	0
9/29/58	20:00	:00	0		:00	:49	0
9/30/58	20:00	:00	0		:00	:45	0
Totals	396:13	23:47	30		0	27:44	2

Seminar

"Digital Computers in the USSR", by Dr. James E. Robertson, September 29

Personnel

The personnel associated with the department, and, hence, the contributors to this report are:

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Belford , Geneva G. , 1/2-time Research Assistant (started September 16)
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Chow, Yuan S., Research Associate
Clark, Miss Helen B., Secretary
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TECHNICAL PROGRESS REPORT

PART I	-	HIGH-SPEED COMPUTER PROGRAM
PART II	-	SWITCHING THEORY
PART III	-	MATHEMATICAL METHODS
PART IV	-	GENERAL RESEARCH
PART V	-	ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

October, 1958

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission, in part by Contract Nonr-1834(15) of the Office of Naval Research and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

The Rich Electronic Computer Center at Georgia Institute of Technology is participating in this work by the support of a staff member at the University of Illinois.

1. Shifting Register Test Unit

Debugging of the shift test unit was started on October 1, 1958. Initially, several wiring errors such as resistors of the wrong value and reversely connected diodes, as well as wrong lead connections, were found. Some solder connections also required resoldering. (it should be pointed out that tracking down such faults is very difficult due to the lack of isolation between circuits.) An accidental shorting of the +25 v bus to a gate driver output, made possible because voltage and signal pins are adjacent (see comments on packaging), caused 15 transistors and 27 diodes to be shorted.

One of the more difficult problems was finding out why the auxiliary counter did not operate properly. It turned out that the 3 C-elements were not speed-independent as was expected, which caused extraneous transitions to occur. The difficulty can be explained as follows.

If two switching amplifiers are driven by a common source, they switch, by no means, simultaneously. This is due to the fact that the discrimination levels at the inputs vary with the hardware used (v_{eb} forward, for example, is different from transistor to transistor) and are also a function of the recent history, i.e., ionization, of the switch. This simultaneity of paralleled switches was assumed in the design of the auxiliary counter; the counter failed with slow input waveforms.

The frequency divider, consisting of two F-elements, which feeds the three C-elements was found to emit spurious spikes because two 5 v Zener diodes in series were used instead of one 10 v Zener diode. Two Zener diodes in series cannot replace a single Zener diode because the voltage-current characteristic near the breakdown voltage is no longer linear. The effect is that pulses are emitted when the Zeners are brought out of conduction. Transmission of these pulses was blocked by the insertion of a diode.

At this point, the unit still failed to work reliably. Transistors were tested, and those which were outside the tolerance limits were replaced. One source of trouble was also noise on the voltage buses which frequently exceeded the ± 3% tolerance, and in some instances was as high as 15%. Due to the low impedance level of the circuits, even 0.1 μf capacitors were sometimes insufficient to bypass all noise.

After all voltage buses had been bypassed to bring the voltages within the ± 3% tolerance band, the unit worked for several hours. The basic shift cycle time was 540 mμs for one up gate and one right or left down gate. Reasons for the relative slowness of operation are not apparent at this point.

The packaging of the units is considered unsatisfactory for the following reasons:

(i) signal pins and power supply pins are too close together; due to the high currents which the power supplies can furnish, an accidental shorting of a signal pin to a supply pin is catastrophic;

(ii) many components, especially diodes, should be more accessible for checking and replacement purposes;

(iii) there are not enough test points.

(G. Metze and H. Lopeman)

2. Core Storage

As reported previously, an order has been placed for a single core plane having 64 words of 53-bit length and two cores per bit, for 64 extra switches and for 8,192 extra storage cores. Tests were planned during the month for measuring delay time, attenuation, characteristic impedance, cross-talk, heating effects,

signal amplitudes, etc., when the core equipment is received.

In connection with these forthcoming tests, a design for the X and Y drivers (and also B drivers) has been arrived at which, according to initial calculations, is capable of providing current pulses of up to 750 ma at 50% duty cycle with a rise time of 50 mμs (nominal) and a current regulation of ± 7.5% over tube life. This design has the major disadvantages that an initial adjustment for screen-grid current must be made, and that a large steady power drain exists (perhaps as much as 3 kw for all drivers). This design has not been tested although rather similar designs have.

(S. Ray)

3. Over-all Design

A number of changes in detail in the order code have been made, mainly to eliminate unnecessary orders. Some orders have been added, for example,

(a) add to the next instruction the address taken from the core memory location specified by this instruction (add m to next M);

(b) set B of the next instruction to be the least significant four bits from the address of this instruction (set next B from M).

These, together with "add M to next m", may be repeated as often as necessary to give a very general form of address construction. Very fast interpretive subroutines can be written, using few instructions.

On the initiation of a program interrupt, the contents of the control counter, the overflow digits of A, and other information necessary to reconstruct the state of the machine, are stored automatically. Also, the overflow digits of A are set to indicate no overflow to prevent an interruption when A is later stored.

(W. Gear and D. Gillies)

4. Input-Output and Auxiliary Storage

Various schemes of building binary counters are being investigated to meet several different requirements in the input-output equipment. The so-called thyristor, a mesa-type transistor with regenerative characteristics, seems to offer some simplifications in circuitry. The switching characteristics of the thyristor

may also be useful in magnetic tape writing circuits.

(T. Murrell)

Tolerance analysis was completed for the diode switching array designed as part of a programmed pulse train generator to be used in testing magnetic tape recording circuits and components. Work was started on design of a suitable four-stage counter for use in the pulse train generator.

(R. Cummins)

A single-shot gate was designed, checked on Illiac by program no. 1206, and tested in a bread-board setup. The gate length can be varied from 10 μs to 25 μs. Three GE 2N43 transistors were used in the test. This circuit was designed for use in experimental determination of drop-out characteristics of the magnetic tape recording system.

(C. Liu)

PART II

SWITCHING THEORY

(Supported in part by the Office of Naval Research under Contract N6ori-07130)

Self descriptive programs for an idealized computer have been written as part of the project to obtain a self-contained logical system. These programs are analogous to checking programs and have the property that they serve to distinguish the given computer from other conceivable systems. Four variations from the given computer were treated.

(a) For all machines, each order affects a transfer of information $\frac{\alpha_1}{\alpha_2} \rightarrow \frac{\alpha_3}{\alpha_4}$, plus a transfer of control to location α_5. Assuming the order is written (a b c d e), we set $\alpha_5 = 3$ and allow the set $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ to be any permutation of a, b, c, d.

(b) Similar to (a), except that we allow each of $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ to take on any of the values a, b, c, d, e. For example, one variation would be a machine which uses "a" for all α's, and simply brings about the transfer $\frac{a}{a} \rightarrow \frac{a}{a}$.

(c) Similar to (b), except that there we assumed that machine behavior was completely independent of the location of the order, while here we assume that outside of a given fixed set of memory locations (within which behavior is constant), the variation [from among the class of 625 variations defined by (b)] may depend upon the location of the order. This program, therefore, checks the behavior at an arbitrary memory location.

(d) An extension to the case where more than one symbol transfer might be affected by one order was left incomplete. The difficulties here seemed tremendous.

An attempt was also made to describe a simple mathematical system (a group) using idealized computer instructions. It is hoped that suitable self-descriptive programs may be used to provide proofs of theorems and metatheorems of the system.

(G. Belford)

PART III

MATHEMATICAL METHODS

1. Hydrodynamic Flows with Shocks (Supported in part by the National Science Foundation under Grant G2794.)

The problem of a steady-state shock being overtaken by a centered rarefactive simple wave was solved numerically by several different procedures as a means of comparing these procedures in their applicability to problems involving time-varying shocks.

The difference equations employed were of the form

$$M_k^{n+1} = M_k^n + Q^n_{k-\frac{1}{2}} - Q^n_{k+\frac{1}{2}}$$

$$P_k^{n+1} = P_k^n + R^n_{k-\frac{1}{2}} - R^n_{k+\frac{1}{2}}$$

$$E_k^{n+1} = E_k^n + S^n_{k-\frac{1}{2}} - S^n_{k+\frac{1}{2}}$$

where M_k^n is an approximation to the density at the point (x_k, t_n):

$$x_k = x_o + k\Delta x$$

$$t_n = t_o + n\Delta t \quad ;$$

$P_k^n = M_k^n U_k^n$ and U_k^n approximates the fluid velocity at (x_k, t_n), and

$E_k^n = M_k^n E_k^n = M_k^n (U_k^n + \frac{1}{2} U_k^{n^2})$ and U_k^n approximates the internal energy at (x_k, t_n).

For the "generalized Lax equations"

$$Q^n_{k+\frac{1}{2}} = \frac{1}{2} r \left(M^n_k u^n_k + M^n_{k+1} u^n_{k+1}\right) + \theta\left(M^n_k - M^n_{k+1}\right)$$

$$R^n_{k+\frac{1}{2}} = \frac{1}{2} r \left(P^n_k u^n_k + p^n_k + P^n_{k+1} u^n_{k+1} + p^n_{k+1}\right) + \theta\left(P^n_k - P^n_{k+1}\right)$$

$$S^n_{k+\frac{1}{2}} = \frac{1}{2} r \left[(E^n_k + p^n_k)u^n_k + (E^n_{k+1} + P^n_{k+1})u^n_{k+1}\right] + \theta\left(E^n_k - E^n_{k+1}\right)$$

where

$$\Gamma = \frac{\Delta t}{\Delta x}$$

$$p^n_k = p(M^n_k, U^n_k)$$

with

$$p = p(\rho, U)$$

the equation of state of the gas. For the Lax equations $\theta = \frac{1}{2}$. The stability condition for these equations was previously found to be

$$\frac{1}{2} r^2 \left(a + |u|\right)^2 \leq \theta \leq \frac{1}{2}$$

where a is the sound velocity.

For the "Runge-Kutta type" equations

$$Q^n_{k+\frac{1}{2}} = r\, M^{n+\frac{1}{2}}_{k+\frac{1}{2}}\, u^{n+\frac{1}{2}}_{k+\frac{1}{2}}$$

$$R^n_{k+\frac{1}{2}} = r\left(P^{n+\frac{1}{2}}_{k+\frac{1}{2}}\, u^{n+\frac{1}{2}}_{k+\frac{1}{2}} + p^{n+\frac{1}{2}}_{k+\frac{1}{2}}\right)$$

$$S^n_{k+\frac{1}{2}} = r\left(E^{n+\frac{1}{2}}_{k+\frac{1}{2}} + p^{n+\frac{1}{2}}_{k+\frac{1}{2}}\right) u^{n+\frac{1}{2}}_{k+\frac{1}{2}}$$

where

$$M^{n+\frac{1}{2}}_{k+\frac{1}{2}} = \frac{1}{2}(M^n_k + M^n_{k+1}) + \frac{1}{2}\, r(P^n_k - P^n_{k+1})$$

$$P^{n+\frac{1}{2}}_{k+\frac{1}{2}} = \frac{1}{2}(P^n_k + P^n_{k+1}) + \frac{1}{2}\, r\left[(P^n_k\, u^n_k + p^n_k)\, u^n_k - (P^n_{k+1}\, u^n_{k+1} + p^n_{k+1})u^n_{k+1}\right]$$

$$E^{n+\frac{1}{2}}_{k+\frac{1}{2}} = \frac{1}{2}(E^n_k + E^n_{k+1}) + \frac{1}{2}\, r\left[(E^n_k + p^n_k)u^n_k - (E^n_{k+1} + p^n_{k+1})u^n_{k+1}\right] \quad .$$

The method previously discussed for taking explicit notice of shocks by making use of the "backward" characteristic through the point (ξ_{n+1}, t_{n+1}), where ξ_{n+1} is the (approximate) position of the shock at time $t = t_{n+1}$, was compared with results of ignoring the shock in the calculation. Ignoring the shock appeared to give accurate results regarding the position of the shock, although values of the state variables (M^n_k, u^n_k, U^n_k) were quite inaccurate near the shock path. The error of each of the variables for either system of difference equations, when the method of taking explicit notice of shocks was used, was of the order of Δx. When the shock was ignored, the error appeared to be of the order of $(\Delta x)^{1/2}$.

In regions where the flow was smooth the Runge-Kutta type equations gave very accurate results, the error being $O[(\Delta x)^2]$. The generalized Lax equations had an error in such regions of $O(\Delta x)$, and were most accurate when θ was taken as small as possible consistent with the stability condition.

(C. Farrington)

2. Iterative Methods for Solving Systems of Linear Equations

(Supported in part by the Office of Naval Research under Contract N6ori-07130)

In order to solve the equations $A\vec{x} = \vec{y}$, we consider the iteration scheme

$$\vec{\eta}_{k+1} = 2b(G\overrightarrow{\eta n} + H\vec{y} - \vec{\eta}_{k-1}) + \vec{\eta}_{k-1} \qquad k \geq 1$$

$$\vec{\eta}_1 , \vec{\eta}_0 \quad \text{given}$$

and

$$G + HA = I \quad .$$

If H is positive definite and symmetric, it can be shown that

$$||\vec{\eta}_k - \vec{x}|| \le \left(\frac{|H|_u}{|H|}\right)^{\frac{1}{2}} \left\{ \max_{j=1,\dots n} \left|\frac{d_{1j}^k - d_{2j}^k}{d_{1j} - d_{2j}}\right| \; ||\vec{\eta}_1 - \vec{x}|| \right.$$

$$\left. + |2b - 1| \max_{j=1,\dots n} \left|\frac{d_{1j}^{k-1} - d_{2j}^{k-1}}{d_{1j} - d_{2j}}\right| \; ||\vec{\eta}_o - \vec{x}|| \right\}$$

$$\le \left(\frac{|H|_u}{|H|_\ell}\right)^{\frac{1}{2}} \left\{ \max_{\substack{i=1,2\\ j=1,2\dots n}} k|\varphi_{ij}|^{k-1} \; ||\vec{\eta}_1 - \vec{x}|| \right.$$

$$\left. + |2b - 1| \max_{\substack{i-1,2\\ j=1,2\dots n}} (k-1)\,|\varphi_{ij}|^{k-1} \; ||\vec{\eta}_o - \vec{x}|| \right\}$$

where φ_{ij} are the roots of

$$\varphi_j^2 - 2b\,\lambda_j\,\varphi_j + (2b - 1) = 0 \qquad ;$$

λ_j are the proper values of G.

The question arises how to choose b so that the number of iterations are as small as possible. One possibility is to choose b so that

$$\max_{\substack{i=1,2\\ j=1,\dots n}} |\varphi_{ij}|$$

is minimized with respect to b. From the above inequality which is attainable, we see that for large k, this will greatly reduce $||\vec{\eta}_k - \vec{x}||$. The b which satisfies this requirement is

$$b = \frac{\bar{\lambda}}{1 + \sqrt{1 - \bar{\lambda}^2}}$$

(G. Golub)

PART IV

GENERAL RESEARCH

(This work is supported in part by the Office of Naval Research under Contract N6oir-07130.)

Monte Carlo Studies

A problem, first raised by van der Corput in 1935, on how uniform a discrete distribution can be is being studied. This problem has applications in Monte Carlo integration. A partial solution of this problem was obtained by K. L. Roth in 1954 (Mathematika 1, 73-9). Hammersley has solved a related, but much simpler, problem of minimizing the variance of the gap lengths of a discrete distribution in one dimension: it was shown that, when the distribution is taken on the unit interval, the coordinate of the nth joint should be at the fractional part of $\log_2 (n + 1/2)$.

(J. Hammersley)

A program, known as Spinnaker, is being prepared to treat the body-centered-cubic Ising lattice in the presence of an external magnetic field. This code uses a Monte Carlo sampling scheme like that used in the Incubus program (University of Illinois, Digital Computer Laboratory, File No. 254, September 9, 1958). Methods of treating the Heisenberg model of a ferromagnet, a more realistic model than the Ising lattice, are being investigated.

(D. Handscomb and L. Fosdick)

A program is being prepared for estimating, by Monte Carlo methods, the elements of the transition matrix for various symmetric spatial partitions of a uniform, spherical reactor (isotropic scattering, two secondary neutrons at each collision).

(J. Beardwood)

A program for Monte Carlo matrix-inversion, with a sequential sampling process, is in preparation.

(J. Halton)

A program has been written, following the method of Erpenbeck and Wall for the generation of long self-avoiding walks on the tetrahedral lattice. It is expected that walks with a mean square length of 4.10^3 (steps^2) will be generated. The increased chain length has been achieved by more efficient coding of the individual steps.

(J. Halton and P. Marcer)

PART V

ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

Machine Use

During October specifications were presented for 23 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1216. Numbers followed by T are for theses.

1216 T Physics. Cryogenic Temperature Measurements. At low temperatures the resistance of a carbon resistor can be used to measure temperature by plotting $\sqrt{\frac{\log R}{T}}$ vs. log R; the plot is very nearly linear. The program will compute linear least-squares constants, and deviations for a correction curve, from a number of standard temperature-resistance values. These are then used to convert additional values of R into the appropriate values of T:

$$T = \frac{\log R}{(A + B \log R)^2}$$

, where A and B are the computed least-squares intercept and slope.

1217 State Water Survey. Reservoir Sedimentation. Field surveys were carried out by the Water Survey on lakes in Illinois to measure the volume of water and sediment in each lake. Ten such lakes were surveyed during 1958 as a part of a continuing research program to measure reservoir sediment. Illiac will be used to reduce and evaluate the data from each lake.

1218 T Physical Chemistry. Potential Energy Surface Calculations. In order to solve problems of theoretical chemical reaction rates, the rate constant must be known. To obtain this, several items must be known, among which are the "activation energy" of the reaction and the "transmission coefficient" across the potential barrier. One way to obtain the transmission coefficient is to utilize Hamilton's classical equations of motion for a frictionless particle sliding on a potential energy surface. However, no entirely satisfactory relation between the

potential energy and the interatomic distances has been found. The purpose of this problem is to use an empirical relation to obtain a surface from which the transmission coefficient may be calculated. The differential equations obtained from Hamilton's equations must be solved by numerical means. Upon doing this for a sufficient number of initial conditions, the transmission coefficient is calculable.

1219 T Mechanical Engineering. Calculation of Aerodynamic Properties of a Supersonic Flow by the Three-Dimensional Method of Characteristics. It is intended to develop a code for Illiac to calculate the aerodynamic properties of a general body in supersonic stream by the three-dimensional method of characteristics. The three-dimensional field is divided into many small tetrahedrons, starting from the initial known region. Each divided region is calculated by solving six simultaneous algebraic equations with iterated coefficients.

1220 Michael Reese Hospital, Chicago. A Study of Psychiatrists' Ratings of Mental Patients. The ratings by psychiatrists of several classifications of mental patients will be studied with several problems in mind. First, the reliabilities of these ratings will be investigated. Ratings of a special research team of psychiatrists are to be compared with those of the resident psychiatrists who are working with the patients. Stereotypes in ratings will be investigated, using factor analytic procedures. Scores on factors derived from ratings will be determined and correlated with external variables.

1221 T Chemistry and Chemical Engineering. Spectral Analysis for Molecular Structure Studies. Absorption spectra of molecular species provide information useful in the theoretical study of molecular structure. Frequently, the bands of these spectra overlap to such an extent that the location and magnitude of the contributing bands cannot be accurately determined except by analysis of the spectrum into components. The numerical analysis of spectra into component bands is simple in principle, but very tedious in practice. The presently planned approach to this problem on Illiac involves fitting bands, assumed to be of Gaussian shape, to the apparent maxima of absorption in the spectra and refining these approximations to a least-squares fit by variation of one band parameter at a time.

1222 Animal Science. Lysine Requirement. This problem is to determine the optimum requirement of the amino acid lysine for swine. By the use of Illiac a least-squares fit will be used to obtain this point. Programs written under specification 1053 will be used.

1223 Physics. Magnetic Field Calculations. The problem is to evaluate the harmonic components of the University of Illinois cyclotron's magnetic field. For this evaluation the magnetic field must be calculated as a function of angle and radius for each field, giving a total of approximately 750 points per field.

1224 T Chemistry. Nuclear Magnetic Resonance Spectra - 4 Spin System. The appearance of the nuclear magnetic resonance spectrum of the substituted benzenes depends on the chemical shifts and coupling constants of the protons in the molecule. This dependence is reflected in a correlation of the different substitution types with the complexity of their nuclear magnetic resonance spectra. This problem involves the computation of the spectra of typical examples of a number of different substitution types, and a correlation of these spectra with the type of substitution. The results should yield a convenient and serviceable method of determining the type of substitution in a large group of important compounds. These calculations will be carried out by means of an automatic program for calculating the spectrum which theoretically should result from a given set of chemical shifts and coupling constants for a system of n nuclear spins $(n = 6)$.

1225 Psychology. Automatic Rotation of a Plot of n Variables. An automatic rotation of a plot of n variables $(n \leq 150)$ in k dimensions $(k \leq 20)$ is effected in such a manner as to obtain a unique pattern of their projections, namely that pattern in which the maximum number of projections is minimized. This operation is required in all factor analytic work in psychology and the social sciences.

1226 Chemistry and Chemical Engineering. Analysis of Nuclear Magnetic Resonance Spectra. The general problem entails the analysis of high resolution nuclear magnetic resonance spectra. Experimental spectra are obtained and, depending upon their complexity and previous experience, approximate values are deduced from the

spectra for the physical parameters governing the appearance of the spectra. These values are then used with routine 1202T to calculate the transition frequencies and the intensities. This routine is a general routine developed for calculating eigenvalues and eigenvectors for up to six nuclear spins with $I = \frac{1}{2}$. It entails computation of the matrix elements and feeding the results into the standard library routine M4 which is made an integral part of 1202T. The spectrum is then calculated, simplified (close transitions combined) and printed out. The parameters are varied systematically until "satisfactory" agreement is obtained between observed and calculated spectra.

1227 T Civil Engineering. Behavior of Arches Under Dynamic Loads. This investigation is concerned with the response of arch structures under dynamic loads. Both inelastic and elastic behavior will be studied. The problem has been simplified by replacing the continuous arch by an analogous framework consisting of a series of straight bars and joints. The problem of determining the dynamic response is essentially one of satisfying the equations of motion for each of the masses. These equations can be solved numerically using a step-by-step method of integration. It is proposed to use library routine F3-129 or a modification thereof for this investigation. The auxiliary routine of F3 will evaluate the internal and external forces of the structure at each joint. These forces are expressed as functions of the displacements at the joints.

1228 Control Systems Laboratory. The Growth of Small Water Waves with Wind Speed and Fetch. The problem involves least-square fits on non-linear equations, with variation of six parameters (not all independent)and several sets of physical data.

1229 Psychology. Religious Attitudes as Measured by the Semantic Differential. Illiac will be used on a problem related to the psychological study of religious attitudes. The data was obtained by administering a form of the semantic differential to 85 undergraduates in Introductory Psychology at the University of Illinois. The purpose of this present request is to obtain a correlational matrix on 110 items of information on each of 85 subjects. This matrix will be used to analyze the present data for improving the present form of the semantic differential for further research.

1230 Psychology. Factors Affecting Attitude Change. Several individual studies are to be done in the area of the production of attitude and opinion change via communication processes. Several of the following types of variables are to be studied in their relationship to attitude change:

(1) motivational factors, such as anxiety, etc.;
(2) communication context variables;
(3) message structure variables.

The Illiac will be used to obtain means, standard deviations, intercorrelations, difference scores and factors from these variables.

1231 Sanitary Laboratory. Linear, Mean-square Regression of Data on Impurities in Water. The data consists of the results of chemical analyses--specifically, parts of impurity per million versus time. The range of the data is about 10^{-2} to 10^{-4} in both coordinates; although for each particular run, the range may be much less. The curve $y = mx + b$ is fitted to the data according to the best mean-square fit.

1232 Computer. Oblimax Rotation of Factor Vectors. The oblimax rotation method of factor analysis is to be revised and extended. The new revisions will eliminate certain portions of the tape preparation and will also be more versatile in that various common subsequent computer operations on the data will be included as options.

1233 T Electrical Engineering. Rebatron Characteristics. Illiac will be used to study the solution for the output characteristics of an electron axially traversing a right circular cylindrical microwave cavity which is operating in the TM_{010} mode. This is an extension of problem numbers 117 and 418 to a different phase of the problem using different parameters and constants.

1234 T Civil Engineering. Dynamical Response of a Three-Span Continuous Highway Bridge. Numerical integration techniques will be used to investigate the behavior of a continuous highway bridge under the influence of moving vehicles. The problem consists of several steps:

(1) obtain the influence coefficients of reaction;
(2) obtain the natural frequencies of the structure;
(3) numerically integrate to get the response of the structure to the moving loads.

1235 Sociology and Anthropology. Lincoln Sociometric Study. The Illiac will be used to investigate the sociometric relations among mildly mentally retarded boys in a ward at the Lincoln State School. The data pertain to choice of meal partners made by 77 boys. An observer recorded the choice made by the boys for 34 separate meals. The boys had an ample opportunity to choose meal partners. It is proposed to determine the factor structure of a set of proportions. The proportions are the number of times two boys chose to sit together to the number of possible meals they could eat together. The method used will be to extract centroid and principal axis factors over the set of proportions. This will be followed by the standard oblimax routines.

1236 Computer. Spinnaker. This program is designed to estimate long-range order and short-range order parameters in the body-centered-cubic Ising lattice as a function of temperature and external magnetic field. The size of the spin array is variable being either 4, 8 or 16 unit cells on an edge. Periodic boundary conditions are imposed to approximate the effect of an infinite lattice. The method of calculation is a Monte Carlo sampling scheme similar to that used in the INCUBUS program (problem number 1192).

1237 Physics. Photomeson Cross Section. The dispersion relations yield a complicated algebraic expression for the differential cross section for photopion production. This expression involves about six different empirically determined parameters, and it also includes the effects of a number of interactions, some of which are of better standing than others. Since experimental data do not fit the theoretical predictions very well at many values of energy and angle, it is of interest to explore the effects of changing the values of some of the parameters, and of dropping out entirely some of the less well known terms.

1238 Marketing. Factors Affecting Expenditures of the Aged. This is a study of the factors involved in the consumption of the aged. In this instance, consumption of food, clothing, and housing is to be studied. A sample of 1757 families is being studied in respect to 26 variables. The data were obtained from the 1950 Bureau of Labor Statistics' Survey of Expenditures. We are interested in determining the interrelationship of the variables involved and in extracting the most important ones, using the varimax and oblimax methods.

Table I shows the distribution of machine time for the month of October.

TABLE I

	Hrs:Min	
Regular Maintenance	26:25	
Unscheduled Maintenance	4:03	
Drum Engineering	50:19	
R.A.R.	7:59	
Leapfrog	37:57	
Program Development	:38	
Wasted	:00	
		127:21
Use by Departments		
Computer	74:17	
Physics	31:49	
Control Systems Laboratory	97:33	
Structural Research	57:12	
Struct. Res. (AF 464)	6:18	
Theor. and Appl. Mech. (ORD 593 IC)	1:21	
Psychology	29:41	
Inst. of Com. Res.	1:39	
Inst. of Com. Res. (9067C)	4:51	
Electrical Engineering	12:55	
Elect. Eng. (AF 6079)	:08	
Mechanical Engineering	20:48	
Mech. Eng. (ORD 1980)	:49	
Mech. Eng. (Inst. of Boiler Rad. Mfg.)	:05	
Mech. Eng. (AF 3789)	:19	
Chemistry	37:25	
Agriculture	13:52	
Economics	8:31	
State Water Survey	2:18	
State Water Survey (SC 75055)	1:34	
Bureau of Educational Research	4:32	
Education	6:37	
U. of Michigan (Mental Health)	1:21	
Classes	:24	
Demonstrations	1:24	
Miscellaneous	26:42	
		444:25
		571:46

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7 a.m. and 11 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 11 a.m. together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive, from an error standpoint, to look at the periods between 11 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared, using the period between 11 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. During the 5:30-6:30 period (when the machine is checked) if no errors are found, the time is given to the "running" column. Each failure was considered to have terminated a running period and was follwed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for October.

TABLE III

Input-output	2
Memory	1
Power Supply	1
Drum	11
Operator Error	1
Maintenance Error	1
Unknown	2
Total	19

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
10/1/58	19:58	:02	2	(1) Input Failure (2) Input Failure	:00	1:00	0
10/2/58	19:03	:57	1	(1) Drum Failure	:00	:56	0
10/3/58	18:22	1:38	3	(1) Drum Failure (2) Drum Failure (3) Drum Failure	:00	:40	0
10/6/58	19:49	:11	1	(1) Drum Failure	:00	1:01	0
10/7/58	19:23	:37	2	(1) Drum Failure (2) Williams Memory 2^{-28} $0 \rightarrow 1$	:00	:39	0
10/8/58	20:00	:00	0		:00	:48	0
10/9/58	19:16	:44	1	(1) Fuse blew in +300 v power supply	:00	:43	0
10/10/58	18:41	1:19	1	(1) Drum Failure	:00	:53	0
10/13/58	20:00	:00	0		:00	:47	0
10/14/58	20:00	:00	0		:00	:39	0
10/15/58	18:00	2:00	1	(1) Drum Failure	:00	:24	0
10/16/58	20:00	:00	0		:00	:46	0
10/17/58	20:00	:00	0		:00	:49	0
10/20/58	20:00	:00	0		:00	:39	0
10/21/58	19:49	:11	2	(1) Drum Failure (2) Unknown	:00	:42	0
10/22/58	20:00	:00	0		:00	:46	0
10/23/58	20:00	:00	0		:00	:39	0
10/24/58	19:13	:47	1	(1) Drum Failure	:00	:45	0
10/27/58	19:39	:21	2	(1) Drum Failure (2) Unknown	:00	:39	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUP-TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
10/29/58	20:00	:00	0		:00	:39	0
10/29/58	19:59	:01	1	(1) Operator Error	:00	:41	0
10/30/58	20:00	:00	0		:00	:40	0
10/31/58	19:59	:01	1	(1) Maintenance Error	:00	1:07	0
TOTALS	451:11	8:49	19		:00	17:22	0

Reports and Seminars

Reports

No. 85, "Some Flipflops", by K. C. Smith

No. 86, "A Set of Basic Circuits", by G. H. Leichner

Seminars

"Flow Charts Methods for the Logical Design of Asynchronous Control" by Dr. David E. Muller, October 6

"The Over-all Design of the New High-Speed Computer", by Dr. D. B. Gillies, October 13

"Input-Output System for the New Computer", by Richard L. Cummins, October 20

"Monte Carlo Computations on Some Configuration Problems in Solid State Physics", by Dr. Lloyd D. Fosdick, October 27

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TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM
PART II - SWITCHING CIRCUIT THEORY
PART III - MATHEMATICAL METHODS
PART IV - ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

November 1958

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission, in part by Contract Nonr-1834(15) of the Office of Naval Research and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

The Rich Electronic Computer Center at Georgia Institute of Technology is participating in this work by the support of a staff member at the University Illinois.

1. Shifting Register Test Unit

After all voltage buses had been bypassed, the unit ran for several nights without failure. The time for one complete shift, consisting of one up shift and one right or left down shift plus control operations, was 540 mμs. In order to speed up the basic shift cycle the gate return loops were shortened (to the point where the unit began to fail) by replacing the checking circuitry with level restorers in lieu of delays. These failures could be attributed to the following conditions: Spurious gate pulses appeared because of noisy inputs to the gate drivers. It is also conjectured that the type A flipflops in the shift counter could not be set reliably (during the shortened gate time) by the small currents which diode AND circuits can furnish. Several transistors and diodes were found to be faulty or marginally faulty, partly as a direct result of another accidental shorting of a voltage bus to a driver output.

After the gate drivers had been modified to make the input stage less sensitive to noise and after the shift counter flipflop had been modified to the AJ design, the level restorers in all return loops, except the up-gate return loop, could be removed and the unit still ran reliably. The shift time was 280 mμs.

A redesign of the control to eliminate a C-element brought the shift time to 260 mμs.

After a replacement of some marginal transistors, it was possible to connect the up-gate return directly. This reduced the shift time to 235 mμs. The

unit ran at this speed for 188 hours and then failed (on December 4), because a transistor in a shift register flipflop exhibited an extremely high V_{EB} forward, and possibly because the -2v voltage bus for that register was not sufficiently bypassed.

(H. Lopeman and G. Metze)

2. Multiplier Test Unit

During the month logical design was begun for a multiplier test unit to do the following simultaneously:

(a) multiply continously;

(b) compare the product obtained with the correct answer;

(c) read from, and write into, a flow-gating memory.

The arithmetic portion of this unit comprises

M a short single-rank multiplicand register
$(A,\bar{A})$ a short double-rank sum register
$(C,\bar{C})$ a short double-rank base 4 carry register
A pseudo adder whose output is connected to $\bar{A},\bar{C}$
A complementing and doubling circuit connecting M to the pseudo adder
$(Q,\bar{Q})$ a double-rank, long-shifting register of non-standard design, to be described later.

During multiplication, base 4 recoded multiplier digits are sensed at the least significant end of Q, and cause the setting of the complement gate for the successive steps in multiplication. If no addition takes place in a step, A,C are gated straight up to $\bar{A},\bar{C}$; otherwise, they are combined with a multiple of M in the pseudo-adder, whose output is then gated to $(\bar{A},\bar{C})$. A down-shift gate 2 binary places to the right connects $(\bar{A},\bar{C})$ to (A,C) and digits at the left-hand end of Q. (A partial assimilation is necessary to prevent carry digits from going to Q, but by introducing an extra flipflop in the carry register, this is essentially just an end connection. Similarly, $(A,\bar{A})$ and $(C,\bar{C})$ and the pseudo-adder are extended to the left so in right shift the true sign digit of the partial product is duplicated.

A portion of the Q register (towards the right-hand end) consists of two relatively short registers $(Q_1,\bar{Q}_1)$ and $(Q_2,\bar{Q}_2)$ of equal length, say 2k. $\bar{Q}_2$ is

connected by the down right gate to the digits to the right in Q, so digits inserted in Q_2 fprm the multiplier. The down gate in Q_1 is a base 4 left shift, and, after each down shift, the 2 left-most digits of Q_2 are compared with the product digits immediately to the left in Q, so the digits inserted into Q_1 consist of portions of the true product (stored backwards and from the least significant end). Checking and continuing the multiplication therefore requires that every k^{th} base 4 shift, Q_1 and Q_2 be set, not from $\bar{Q}_1$ and $\bar{Q}_2$, but from N, a 4k-bit buffer register N, which allows "words" (of 4k bits each) to be read from a flow-gating memory to Q. Suppose that there are p meaningful words in this flow-gating memory, but p+1 registers (exclusive of the N-register). Then a typical sequence would be:

Arithmetic Unit

(1) down gate to $\bar{A}$, $\bar{C}$ and all of Q except Q_1, Q_2; gate from N to Q_1, Q_2;

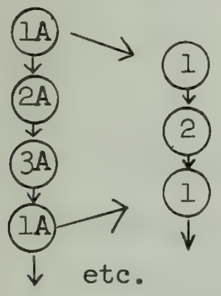
(2) perform k steps of multiplication (k comparisons, k pseudo-adds or up gates, and k-1 down gates);

Memory and Counter

(1A) read from flow gating register i to N
(2A) store N in flow-gating register i-1
(both i and i-1 are available in a suitably-designed counter)

(3A) increase i by one mod p+1 in the counter.

The partial ordering of these events in time is



The parameter k is adjusted so that the flow-gating memory is operating nearly continuously, and the multiplier is operating continuously.

It can be shown that if the number of digital positions in the multiplier is, say, at least 4 more than the number of digital positions in M, there is

practically a free choice for multiplier and multiplicand. The multiplier is a sequence of 2pk bits used repeatedly, and the condition that the product digits are cyclic with period 2pk is equivalent to saying that the value of the number in $(\bar{A}, \bar{C})$ recurs each pk base 4 multiplication steps. If x is the initial contents of $(\bar{A}, \bar{C})$ and m is the contents of M, and s is the multiplier, then in pk steps the product $ms + 4^{-pk} x$ is formed, and checked, starting from the least significant digit. Now if pk is large enough, and ms has both zeros and ones to the right of (A, C) then x can be set equal to the most significant digits of ms without changing the most significant digits of $ms + 4^{-pk} x$. This establishes the required periodicity.

(D. B. Gillies)

3. Basic Circuits

Preliminary work was done on the end connections and drivers of an 8-word (13-bit) flow-gating unit for use in the multiplier test unit. The flip-flops will use selected General Transistor 2N 604 units ($100 \leq \beta \leq 140$), the drivers Western Electric 2N-560 600 mcs transistors of the npn type.

In view of modified specifications of GF 45011 transistors, the set of basic circuits in Report 80 (2nd edition) was modified to require an end-of-life V_{eb} reverse of 4.1v (at 500 μa), retaining a minimum alpha of .93 (end-of-life). The new set of basic circuits is characterized by

(1) smaller swings

$1 \rightarrow +1.3v$ to $+1.9v$

$0 \rightarrow -1.3v$ to $-1.9v$;

(2) smaller tolerance walk-up or walk-down in emitter-follower type ANDs and ORs ($\leq .23v$ with a fan-out of 3);

(3) uniform input requirements: ± 0.6v at max 1.2 ma;

(4) elimination of Zener diodes which are not "on" constantly;

(5) use of S 570-G (Transitron) diodes to replace the present Q5-250 (Qutronics).

The restoring circuits described in Report 86, "A Set of Basic Circuits", were modified to be compatible with the circuits described above. The modifications

involve changing the signal bumping voltages from + 0.9 to + 1.0 and from - 1.9 to - 1.8 volts, and increasing the 770Ω bleeder resistor to 780Ω.

Work was started on a set of basic circuits having much greater swings (0 → - 2.4 or more neg., 1 → + 2.4v or more positive) and using blocking diodes in series with the emitters when necessary. Preliminary calculation shows that not more than .3v drift would occur in an AND and was less in an OR. This means that (with .6v input sensitivity) 6 ANDs and ORs of the emitter-follower type can be cascaded.

This last design would be most helpful in the really fast part of a machine since a whole adder stage can then be designed without a single collector delay. In order to realize this, the ordinary single-wire system would have to be replaced by a two-wire dual system so that push-pull signals are available thoughout.

(W. J. Poppelbaum)

4. Input-Output and Auxiliary Storage

A set of magnetic tape recording head specifications is being written to be submitted to various head manufacturers for comment. The purpose of this is to find out whether heads can be purchased suitable for use with transistor recording circuits at the high data rates necessary for auxiliary storage operations.

An analytical study is being made on the highest density attainable for a recording head with given gap length on the basis of the system response to a step function.

Tape quality control as related to dropout rates was discussed with a representative of one of the major magnetic tape manufacturers. He was informed of the need for reliable recording at densities considerably in excess of the 200 bits/inch commonly accepted as standard in manufacturers' quality control tests. No data was available on dropout rates for such tape at higher densities, but further discussions on this subject are being arranged.

Design of a ring counter for use in the programmed pulse train generator is being studied.

A synchronous binary counter was designed for the magnetic tape recording dropout tester.

Two possible applications of the thyristor are being studied, as a binary counter element and as a magnetic tape head driver. The dc characteristics of three preproduction samples from RCA have been measured, and a circuit has been constructed to measure the energy required to switch from OFF to ON and from ON to OFF. The latter is found to require consistently more energy (measured as $\frac{1}{2}CV^2$) by a factor of the order of 10 or less. This is in contrast to a factor of 1000 published in the first report on the device.

(R. L. Cummins, C. N. Liu,
and T. A. Murrell)

5. Component Procurement and Testing

A first order test was run on 10 Western Electric 1N 673 diodes. The test consisted of biasing the diodes with 25v reverse, pulsing them forward with 400 ma, and then letting them recover to their reverse bias condition with enough resistance in the circuit to limit the enhancement current to 200 ma peak. All the diodes showed a uniformity of enhancement current duration of about ± 20% which would indicate that a much larger sample should be used to give any indication toward whether this type of diode would do the job in an enhancement current re-write memory.

In continuing a previous investigation, some new small, low voltage, low current incandescent bulbs were ordered. All the lamps were from Chicago Miniature Lamp Works. Two models, identical except that one has a base and the other has pigtails, are rated at 60 ma at 5v. They are reasonably bright at 40 ma, but this is about their lower limit currentwise, and this is 10 ma greater than the General Electric No. 342 lamps being used now. The only advantage of the new lamps seems to be their lifetime which is stated as > 60,000 hours. A third type of lamp is rated at 30 ma at 3.5v. This seems like a likely candidate for our readout requirements, but looks of weak physical construction. Some comparative life tests between it and the GE No. 342 should be undertaken.

(J. L. Muerle)

PART II

SWITCHING THEORY

(Supported in part by the Office of Naval Research under Contract N6ori-07130)

1. Semi-modular Circuit Theory

A general representation for semi-modular circuits is being sought which will be analogous to the change chart representation of distributive circuits. The change chart representation is less redundant than the C-state lattice representation and, therefore, is advantageous both for studying the theoretical properties of distributive circuits and for logical design.

This new way of representing semi-modular circuits should retain most of these advantages. A set S of "changes" consisting of integer pairs (α, i) is treated just as in the distributive case, but the relations between these "changes" are somewhat more complicated than the partial ordering which occurred in the distributive case. As yet, the most convenient form of these relations has not been determined and the associated restrictions remain to be worked out.

(J. H. Shelly)

2. Information Transfer in Asynchronous Circuits

A new approach to the problem of information transfer in asynchronous systems is being studied. A few types of simple asynchronous machines are treated as basic units from which large scale systems may be formed. Rules of interconnection are followed which restrict the "fan out" from one unit to the next and provide for speed-independent operation of the system as a whole. Reduction in speed due to the need for excessive current amplification is thus avoided, but the transfer and processing of information is only coordinated locally. Every connection between two units consists of lines passing in both directions. Signal changes on lines in a given connection occur alternately on lines passing in the two directions. Information transfer depends upon the choice of lines passing in a given direction between units and is affected without violating the rules for speed-independent operation.

(D. E. Muller)

PART III

MATHEMATICAL METHODS

1. Iterative Methods for Solving Systems of Linear Equations (Supported in part by the Office of Naval Research under Contract N6ori-07130.)

For the iteration process

$$\vec{\zeta}_{k+1} = 2b(G\vec{\zeta}_k + H\vec{y} - \vec{\zeta}_{k-1}) + \vec{\zeta}_{k-1} \qquad (k \geq 1) \qquad (1)$$

$$\vec{\zeta}_1 = G\vec{\zeta}_0 + H\vec{y}$$

we wish to determine the b such that

$$\max_{\|\vec{\zeta}_0 - \vec{x}\| \neq 0} \frac{\|\zeta_k - \vec{x}\|}{\|\vec{\zeta}_0 - \vec{x}\|}$$

is minimized when k is fixed. If instead of one b we used a sequence of b's denoted as b_k, then the best set of b_k's generate the Chebyshev polynomials. When k = 2, then the optimum b is $b = b_2$. When k = 3, then by matching the Chebyshev polynomials with the polynomials generated by (1), we see that $b = \sqrt{b_2 b_3}$. If $\hat{b} = \lim_{k\to\infty} b_k$, then it can be shown that

$$\lim_{k\to\infty} \frac{\max_{|\lambda| < \bar{\lambda}} P_k(\lambda, \hat{b})}{\max_{|\lambda| \leq \bar{\lambda}} P_k(\lambda, b)} \rightarrow 0 \text{ as } k \rightarrow \infty \text{ for } b \neq \hat{b}.$$

In addition, in the Chebyshev case the number of iterations, k, necessary so that

$$\frac{\|\vec{\zeta}_k - \vec{x}\|}{\|\vec{\zeta}_0 - \vec{x}\|} \leq \epsilon \text{ is } k = \frac{\ln \dfrac{\epsilon}{1 + \sqrt{1 - \epsilon^2}}}{\ln \rho} \quad \text{where } \rho = \frac{\bar{\lambda}}{1 + \sqrt{1 - \bar{\lambda}^2}}, \ |G|_u = \bar{\lambda}.$$

However, for the case $b_k = b$, then the number of iterations k' satisfies $\rho^{k'}(1 + \sqrt{1 - \bar{\lambda}^2}\; k') = \epsilon$. It may be shown that $k' \geq k$, and for $\bar{\lambda}$ fixed

$$\frac{k}{k'} \rightarrow 1 \quad \text{as} \quad \epsilon \rightarrow 0^+ .$$

(Gene H. Golub)

2. Flows Behind Shocks (Supported in part by the National Science Foundation under Grant G-2794.)

A first draft of a report entitled "On Shocks Attached to a Wall in Stationary Two-Dimensional Flows" has been written. In this report a general relation is obtained between the curvatures of the streak lines behind the shock, before the shock and of the shock. The case of normal shocks is studied in detail as is the case of a straight wall.

3. Monte Carlo Methods (Supported in part by the Office of Naval Research under Contract N6ori-07130.)

The SPINNAKER program for treating the body-centered-cubic Ising lattice has been written and is undergoing final code checks. The time to generate one sample configuration is about six seconds for a lattice of four unit cells on an edge. It is anticipated that production computations will begin in December.

(L. D. Fosdick and D. C. Handscomb)

A two-dimensional version of the INTERLINCH program (University of Illinois, Digital Computer Laboratory File No. 254, September 9, 1958) is being prepared. It is planned that, so far as possible, this will follow the pattern that the eventual three-dimensional version will take.

The program for estimating, by Monte Carlo methods, the elements of the transition matrix for various symmetric spatial partitions of a uniform, spherical reactor is undergoing final code checks and is expected to begin production calculations in December.

(J. E. Bearwood)

PART IV

ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

Machine Use

During November specifications were presented for 18 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1239. Numbers followed by T are for theses.

1239 Psychology. Investigation of "Interpersonal Perception" Measures, Psychotherapy. For several years psychologists have been using a complex statistical measure of similarity, D^2. The properties of this measure for various types of data are not well understood, but it seems clear that various results already reported as substantive findings are artifacts of the measure. Various analyses, components, multiple R with outside criteria, and intercorrelation of different D^2 s, have been undertaken here as M.A. theses or parts of research programs. The present program will integrate these attacks and continue the establishment of the properties of D^2 s. A preliminary exploration of D^2 s computed on random and random normal numbers may be initiated on a small scale. A second problem which from time to time is being investigated involves the prediction of progress in psychotherapy from tests. This involves generally an intercorrelation routine plus data transformations and shifts.

1240 T Computer. Reactor Matrix. To investigate the improved efficiency of Monte Carlo methods in estimating multiplication rate and neutron flux in reactors when measurements are made of elements of the "transition matrix" corresponding to a certain partition of the space and energy space is the problem. The case considered is as simple as possible. The "reactor" is a uniform sphere, scattering is isotropic, there are two secondaries at each collision and each neutron has the same energy. Each neutron is tracked, the score recorded and the new coordinates (if any) stored again in preparation for the next generation. The sphere is divided

into sixteen regions, adjacent ones may be combined in any manner and the corresponding eigenvectors and values printed out. Approximately 4,000 neutrons can be dealt with.

1241 Physics. Least Squares. Data on the angular distribution (in the center of mass coordinate system) of negative pions elastically scattered by protons has been taken in a propane bubble chamber. The K3-L7 least squares fitting procedure will be used to analyze these data.

1242 Agricultural Economics. Multiple Correlation Problems. This program is to aid in the study of multiple correlations between output and soil types in the farm management data collected in India. This is of interest in the subject of farm management in agricultural economics.

1243 Economics. Cost Minimization Problem. This economic problem is one of minimizing costs of a given product with regard to the choice of location of stages of production. The production process is split into stages and the product may be produced in either stage at either of two locations. An additional restriction is a given sales requirement in both locations. The Illiac Simplex routine (modified for drum) will be used in the solution of this problem.

1244 Electrical Engineering. Routines for J_0, J_1, Y_0, and Y_1. Since

$$J_n(x) = \frac{1}{\pi} \int_0^{\pi} \cos (x \sin \phi - n \phi)\, d\phi,$$ we propose to use E-5 to give $J_n(x)$ for $0 \leq x \leq 16$. For $x > 16$, we will use the asymtotic expansion. A similar method will be used for Y_n. In both cases of these, $n = 0, 1$.

1245 Psychology. Scoring Purification of Semi-Projective Test. The purpose of the problem is to refine by item analysis a semi-projective test of personality with the purpose of developing new scoring criteria based upon internally consistent factors of item clusters. The raw data will then be rescored (by Illiac if possible) according to the new factor scores. A new factor analysis could then be carried out between the new test results and life data on the subjects in an effort to obtain

phenomenological meaning of the factors. Because of the large number of questions, the item clusters will have to be found through the process of intermeshing phi matrices.

1246 Chemistry. The Length of a Long Chain Polymer. The dimensions of long-chain polymers are of interest in the chemistry of rubber and polymer solutions. The object of the program is to construct samples of a model of such a polymer and estimate the mean square distance between its ends. A polymer of n steps is characterized by n+1 centers linked by n bonds to form a continuous chain on the tetrahedral lattice. The number of successful configurations generated, N, will decrease exponentially with the number of steps, n, i.e., $N = A\exp(-\lambda n)$. This attrition is overcome by an enrichment technique, used by Erpenbeck and Wall (see thesis, Erpenbeck, 1957, and papers to be published in Journal of Chemical Physics). Consider a walk broken into b sections of s steps each; the 1 through i-1 sections complete, and p trials are allowed to complete the next self avoiding section of links. Thus a "tree" of samples is generated and

$$N = p^b \exp(-\lambda s b) .$$

Hence, if $p = \exp(-\lambda s)$, long chains may be generated. So far the method described is that employed by Erpenbeck. However, he stored each link as a lattice vector occupying one word of the store and thus was unable to generate chains of more than 800 steps. In the above program, the lattice vectors are put in correspondence with the integers 1, 2, 3, 4, and each link can, therefore, be stored as two bits. Chains of 3,600 steps are to be generated and information is to be printed out every 72 steps.

1247 Animal Science. Antibiotics in Animal Nutrition. It has previously been shown that when antibiotics are fed to rats deficient in certain vitamins, the deficiency is alleviated. One of the possible mechanisms by which this sparing action of antibiotics takes place is through an increased intestinal microbial synthesis of the deficient vitamin. Since the rat normally consumes a large portion of its feces (coprophagy) it appeared necessary to study the effect of antibiotics on the coprophagic habits of the rat and whether coprophagy is the means by which it obtains the products of intestinal microbial synthesis. The experiments

conducted involved the antibiotics terramycin and rimocidin which were fed to rats deficient in pantothenic acid as well as to control rats. Coprophagy was prevented by means of tail cups. Effects were observed from the growth weights and feed consumption. The mathematical method to be used is the method of least squares. Illiac will be used to calculate the constants and their sampling errors. No complete program has the capacity to handle this problem, so it must be done in several steps.

1248 T Chemistry. NMR Spectra of Aromatic Cpds. This is an automatic program for calculating the spectrum which theoretically should result from a given set of chemical shifts, V_i, and coupling constants, J_{ij}, for a system of n nuclear spins ($n \leq 6$). The program proceeds with this computation through the following main steps:

1. calculation of the machine representation of the 2^n elementary spin-product functions of the form $\phi_{ij} = \prod_{i=1}^{n} I_Z(i)$, where $I_Z(i)$ can be α or β;
2. division of this set of elementary functions into subsets on the basis of total spin;
3. computation of the spin-interaction matrix for each of these subsets using the formulas;
4. calculation of eigenvalues and eigenvectors for these matrices by Illiac Library Routine M4;
5. computation of the spectrum;
6. simplification and print-out of spectrum.

This program is to be used for calculating spectra of a series of aromatic compounds.

1249 Electrical Engineering. Autocorrelation Calculation. This routine will make an analysis of fading rates of signals received by reflection from the moon. The autocorrelation functions are calculated by means of the Illiac. Periodic fading rates are determined from periodic variations of the autocorrelation function.

1250 Computer. Single Divider Synthesis Routine. This is a pilot program for a more general routine and will be used to study the synthesis problem and to assess the value of a Monte Carlo attack. Starting values are taken at random and the circuit is analyzed for all worst tolerance combinations. Its behavior is compared with the specified required behavior and random adjustments are made until all specifications are met.

1251 Control Systems Laboratory. Nerve Net, Model II. This routine will attempt to develop a model of a simple but general associative learning mechanism, based on the assumption that learning consists of the establishment of "connections" between those elements of the central nervous system which are often active at the same time. The central nervous system is formalized in the model to a regular, two dimensional, rectangular lattice of identical elements. Excitation at any point tends to spread to other points, but with a difficulty which increases with the distance. The connectivity is such that, between any two points A, B in the net there exists two major one-way paths, one from A to B, another from B to A, yet these paths share 1/2 their total length in common. Thus, if A and B are simultaneously excited, 1/2 of the common path connecting them will have double use. If sensitivity (conductivity or etc.) of a path is made a function of usage, then communication resistance between points A, B will tend to lower, and, eventually, presentation of a stimulus at A only will quickly lead to excitation of B. Inhibition and temporal summation are employed to emphasize the "connectedness" of simultaneously active elements and to minimize the involvement of elements which may take part in other associations.

Illiac is employed as a logical model of the "nerve" net. Each point in the lattice or net is represented by a memory word in Illiac. Stored in this word is a description of the net point, i.e., its location in the net which indicates the address of its (receiving) nearest neighbors, and its present state due to both past history (Total Count) and present excitation (Increment Count). Generally speaking, Illiac injects excitation (counts) at some point or points during one clock interval. In the next clock interval it scans the matrix of net point addresses and lists those which are in a firing state. This list may be output at this time if the programmer desires. It then executes the "firings", making the concomitant

changes in, and transfers of, counts, and advances the clock by one interval. The computer repeatedly scans the matrix, listing (and outputting) the firing points, executing the firings, and advancing the clock until the number of clock intervals counted since the last input indicates time to make another input. Generally, input frequency f_o is independent of internal firing frequency f_1, except that it is convenient to make them commensurate and to make f_o = some const. x f_1. At chooseable times, Illiac stops and prints out the total counts (times fired) of each of the lattice points, arranging these numbers in a two-dimensional rectangular array topologically related to the lattice which the print-out represents.

1252 T Theoretical and Applied Mechanics. Calculation of Stress Concentrations by the Equivalent Surface Shear Loading. The problem is to compute stress concentration factors in filleted cantilever beams under various loading conditions and to compare these values with those obtained by experimental means. One step in the procedure is to plot stress distributions on a plane through the base of the fillet. This is a very laborious task if attempted by a desk-type calculator. At present it is planned to plot about five different stress distributions.

1253 T Geology. Hydrometer Analysis of Soil. In this investigation the effect of weathering upon certain glacial deposits is being studied. Among other effects weathering should decrease the grain size of the material affected. The depth to which weathering has occurred and, indeed, whether certain soil units are due to weathering or to deposition can be elucidated in part by the grain size variations with depth of the soils involved. In attacking this problem the grain size distribution of 400 to 600 soil samples is being determined. The grain size distribution of the finer portion of each sample is determined by hydrometer analysis of suspensions of the samples in water. The density of the suspension changes with time since the larger soil particles settle out faster than the smaller ones so that a series of readings gives the grain size distribution of the sample. The Illiac will be used to reduce the data.

1254 Aviation Psychology. Generation of Stimulus Event Tapes. An experimental apparatus has been built by the Aviation Psychology Laboratory to investigate human

operator behavior in complex tracking tasks. The apparatus uses a standard 5-hole punched tape reader, which when fed with a coded stimulus tape, activates six display lights, also called stimulus lights, in various configurations. The human operator's task is to respond to the stimulus presentation with the appropriate controls. He has to match the position of switches with the appropriate lights. Various statistical organizations of the stimulus events have been selected for experimental purposes. Each stimulus event on the stimulus tape is a single character and each event is separated by up to 30 zeros for timing purposes. That is, each coded event on the stimulus tape triggers the lights on or off through the tape reader. Then, this particular event (configuration of lights) is to remain on while the tape reader reads the zeros separating each event. Since the reader operates at a rate of 10 operations per second, 30 zeros would be needed between each event character in order that the event last 3 seconds, or 20 zeros for events of 2 second duration.

The use of Illiac will be to provide a speedy method of calculating the coded event characters and spacing these characters with a programmed number of zeros to provide for events of desired duration. The output of this program is a stimulus tape that can be fed directly to our tape reader and produce the exact series of timed events desired on the stimulus lights.

1255 Educational Testing Service, Princeton, New Jersey. Social Desirability Factor Rotation. A set of factors describing social desirability will be rotated to an oblique set of axes using the oblimax procedure.

1256 Student Counseling Service, Chicago, Illinois. Development of Differential Predictive-Index for Predicting Academic Survival and Success in Different Colleges and Curricula. Tests are to be selected from the freshmen guidance examination battery given at the Chicago Undergraduate Division and weighted to give an optimum prediction of grade-point-average and of academic survival in the College of Engineering, the College of Commerce and Business Administration, certain primarily verbal curricula in the College of Liberal Arts and Sciences, and in the Chicago Undergraduate Division as a whole.

Illiac facilities will be used for computation of four 15 x 15 correlation matrices. Only standard library routines are involved.

Table 1 shows the distribution of machine time for the month of November

TABLE I

	Hrs:Min	
Regular Maintenance	15:59	
Unscheduled Maintenance	8:34	
Drum Engineering	31:01	
Leapfrog	35:02	
R.A.R.	6:18	
Library Development	:23	
Wasted	:03	
		97:20

Use by Departments

Computer	21:43	
Physics	23:52	
Control Systems Laboratory	48:49	
Structural Research	62:36	
Structural Research (AF 464)	6:50	
Psychology	30:12	
Psychology (AF-49-638-371)	:40	
Education	7:33	
Electrical Engineering	14:35	
Elect. Eng. (AF 6079)	4:57	
Sociology	4:05	
Chemistry	31:25	
Agriculture	24:32	
Inst. of Com. Res. (9067C)	:48	
College of Medicine	17:09	
Bureau of Educational Research	2:43	
Geological Survey	:50	
Economics	5:45	
Mechanical Engineering	2:34	
Mech. Eng. (AF 3789)	:16	
Mech. Eng. (ORD 1980)	:52	
Mech. Eng. (Inst. of Boiler Rad. Mfg.)	:03	
Sanitary Engineering	:57	
U. S. Navy (9840-0333)	1:16	
State Department of Public Welfare (1715)	3:41	
State Water Survey	1:14	
State Water Survey (46-26-84-312)	:29	
Michael Reese Hospital, Chicago	:51	
Classes	23:18	
Demonstrations	4:13	
Miscellaneous	13:17	
		362:05
		459:25

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7 a.m. and 11 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 11 a.m. together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive, from an error standpoint, to look at the periods between 11 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared, using the period between 11 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. During the 5:30-6:30 period (when the machine is checked) if no errors are found, the time is given to the "running" column. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for November.

TABLE III

Input-output	2
Control	1
Scope	1
Leapfrog	2
Power failures	2
Air conditioning out	1
Drum failures	10
Unknown	1
Total	20

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
11/3/58	16:46	3:14	1	(1) Drum failure	:00	:49	0
11/4/58	20:00	:00	0		:00	:43	0
11/5/58	18:06	1:54	2	(1) Drum failure (2) Illiac air-conditioning system running hot	:00	1:46	0
11/6/58	19:57	:03	1	(1) Input-output failure leapfrog	:00	:37	1
11/9/58	19:59	:01	1	(1) Drum failure	:00	:51	0
11/10/58	19:06	:54	1	(1) Scope error	:00	:42	0
11/11/58	20:00	:00	0		:00	:40	0
11/12/58	20:00	:00	0		:00	:42	0
11/13/58	19:55	:05	4	(1) Input-output error (2) Leapfrog (3) Drum failure (4) Drum failure	:00	3:08	1
11/14/58	19:01	:59	1	(1) Drum failure	:00	:42	0
11/17/58	19:21	:39	1	(1) +300 v. power supply went out	:00	:41	0
11/18/58	20:00	:00	0		:00	:39	0
11/19/58	19:59	:01	1	(1) Input error	:00	:40	0
11/20/58	20:00	:00	0		:00	:55	0
11/21/58	20:00	:00	0		:00	:40	0
11/24/58	19:52	:08	2	(1) Drum failure (2) Drum failure	:00	:45	0
11/25/58	19:46	:14	3	(1) Drum failure (2) Illiac, unknown (3) +300 v. power supply out	:00	:49	0
11/26/58	19:57	:00	0		:03	:48	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
11/28/58	19:38	:22	2	(1) Illiac (control) (2) Drum failure	:00	:52	0
TOTALS	371:23	8:34	20		:03	17:29	2

Reports and Seminars

Seminars

"Monte Carlo Computations on Some Configuration Problems in Solid State Physics", by Dr. L. D. Fosdick, November 3

"Computing at Harwell", by Dr. J. M. Hammersley, November 10

"A Ring Model for the Study of Multiplication in Two's and One's Complement Number Systems", by Prof. H. L. Garner, University of Michigan, Ann Arbor, Michigan, November 18

"Iterative Methods of Solving Linear Algebraic Equations", by G. H. Golub, November 24

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Physics

VERTICAL FILE

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM
PART II - MATHEMATICAL METHODS
PART III - ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

December 1958

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission, in part by Contract Nonr-1834(15) of the Office of Naval Research and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

The Rich Electronic Computer Center at Georgia Institute of Technology is participating in this work by the support of a staff member at the University of Illinois.

1. Shifting Register Test Unit

Attempts to further decrease the basic shift time were unsuccessful. With the present circuitry, further improvements could be obtained by selecting transistors on the basis of dynamic instead of static behavior.

In preparation for another endurance run, all transistors in the unit were checked. Sixteen transistors were replaced because they did not meet specifications. All signals were checked on the scope; marginal signals were traced to seven diodes having low $V_{rev.}$ and one being shorted. The unit then ran without failure for 387.8 hours.

(G. A. Metze)

2. Basic Circuits

Some considerable time was spent investigating in more detail the advantage to be gained from the use of two-wire logic for certain parts of the machine. For the particular case of one base-4 stage of the pseudo-adder, including flipflops and the complementing and doubling circuit, it was shown that the increase in complexity (109 transistors vs. 98) was repaid by a reduction of the (calculated) addition time from 35 mμs to a time between 7 mμs and 14 mμs. This decrease is due to the fact that no collector delays are involved, provided the signal swings are increased according to the proposal in last month's Technical Progress Report. The time of 5 mμs is obtained by assuming a delay of about 1 mμs per emitter-follower stage; this assumption was verified by measuring the delays in cascaded OR and AND circuits. With suitable precautions it may be possible to use two-wire logic for

other applications, and for this reason, level restorers, C-elements and F-elements have been designed. A complete description of the circuits and of their behavior will be given in a technical report which is in preparation.

(N. E. Wiseman and M. N. Schleifer)

A new gating system, using a combination of one AND and one OR circuit which sets a Schmitt trigger flipflop via two diodes, was tested. As can be seen from Figure 1, the up gates are in opposition with the down gates but open as soon as the down gates close and vice versa. This produces the minimum overlap. The selection of left down and right down gates is made by making $s = 0$ (l. d.) and $s = 1$ (r. d.) respectively. A four flipflop unit was built and tested, the g-signal being derived from a clock driving power-stages. The pattern was shifted up to approximately 39 mc, but at 25 mc the swings were already slightly affected. This means that one up and one down shift can certainly be accomplished in 40 mμs.

(W. J. Poppelbaum and G. E. Buenger)

An F-element of novel design was developed (see Figure 2) which uses a bridge-modulator gate at the collector voltage level. This simplifies the circuit discussed in the November Technical Progress Report retaining such desirable features as:

1. high input sensitivity (0.6 v, < 1.2 ma);
2. reduced gating requirements (0.6 v, < 1.2 ma);
3. absence of transients (no long feedback loops);
4. high speed (operation time < 25 mμs).

(N. H. Johnson)

Some preliminary work was done to correlate the results of diode reverse recovery tests and semiconductor as well as circuit theory. The essential difficulties stem from the fact that the recovery times are of the same order as the scope rise times.

(W. J. Poppelbaum)

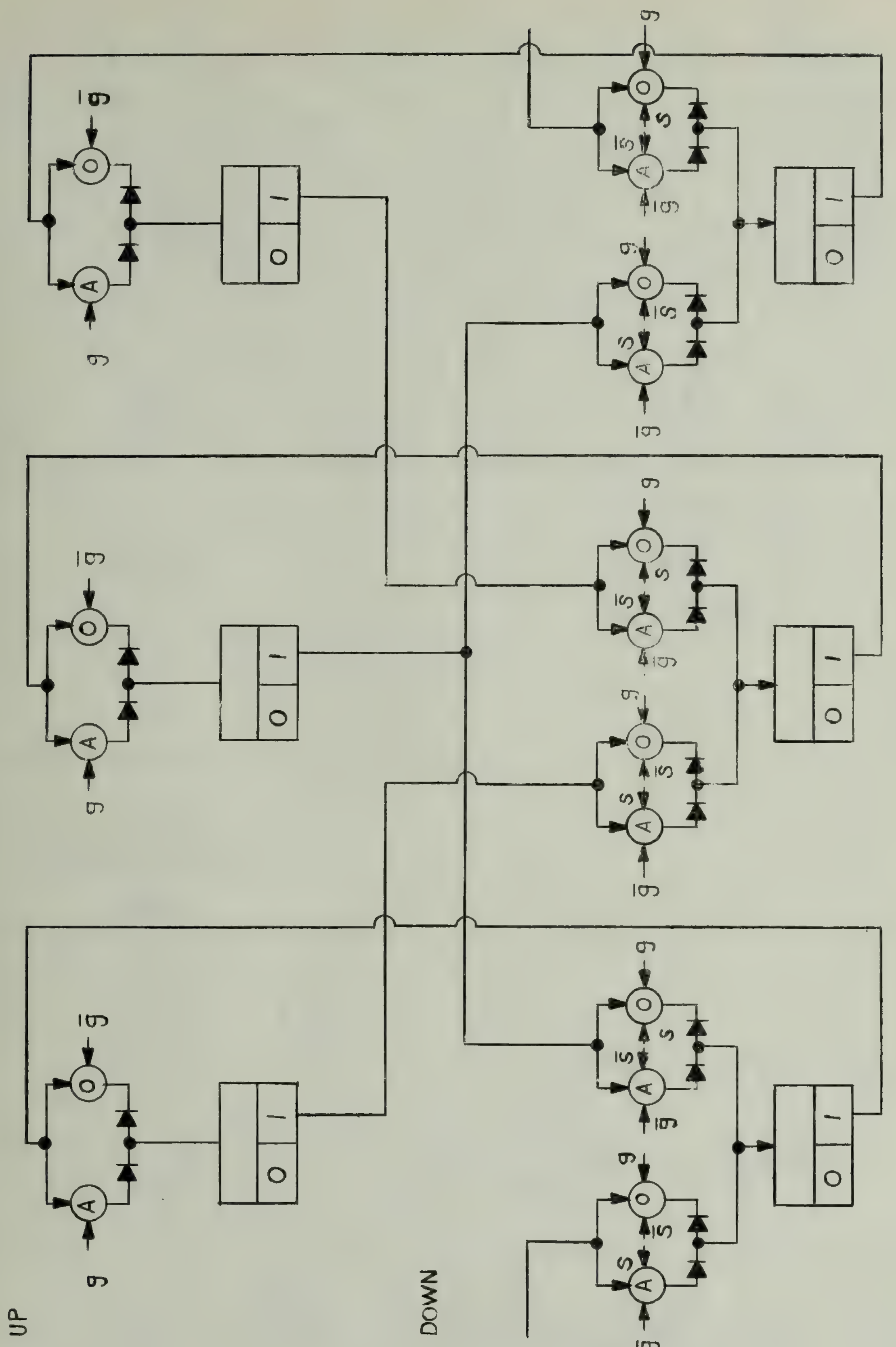
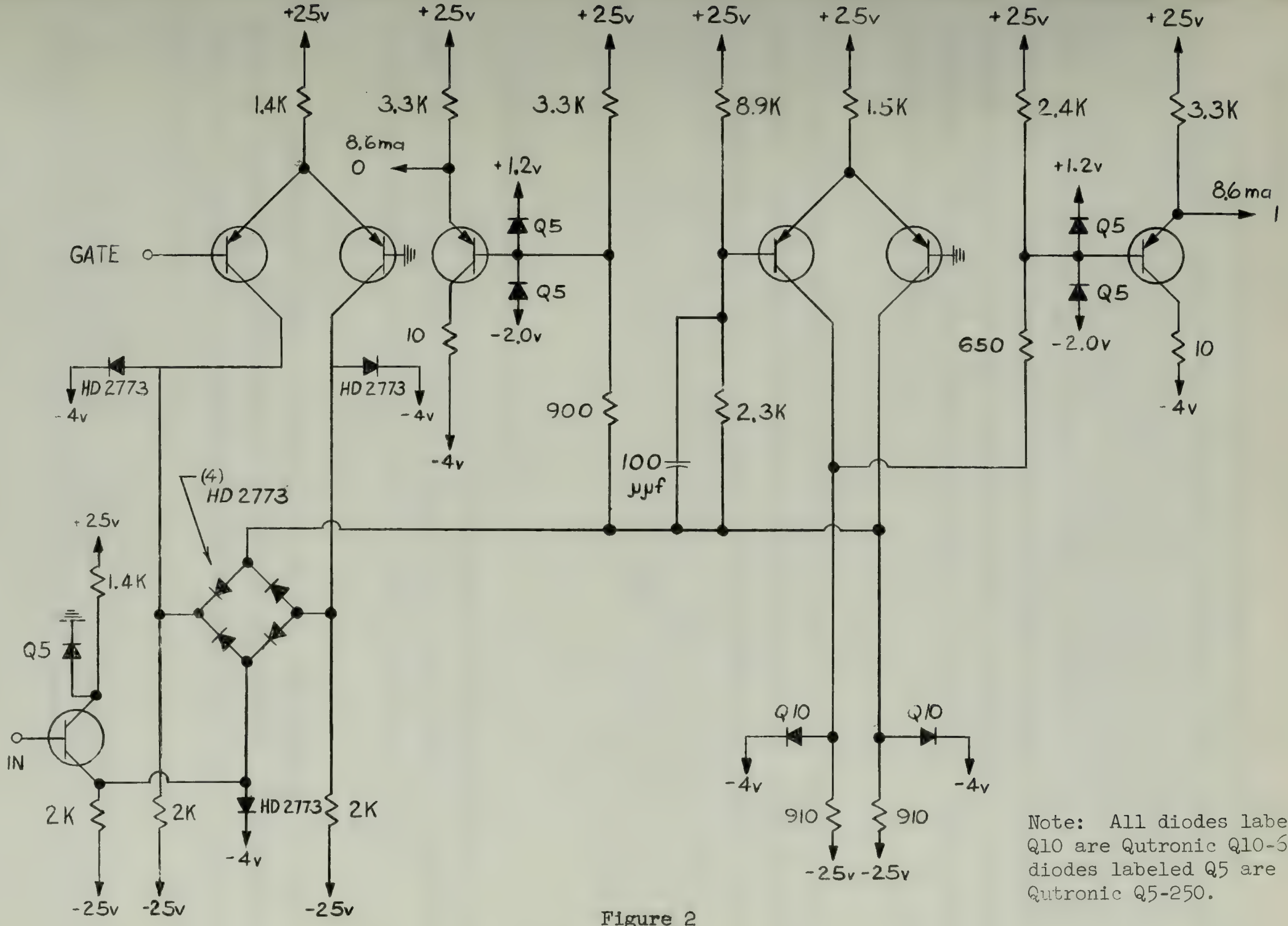


Figure [illegible]

High Speed Gating System



Note: All diodes labeled Q10 are Qutronic Q10-500; diodes labeled Q5 are Qutronic Q5-250.

Figure 2

F-Element
(Operation Time 25 mμs)

3. Core storage

The problem of signal interaction (or "cross-talk") in the memory has been investigated further during the month. In particular, the approximate magnitude of these interactions, especially between sense wires, has been estimated by calculation and by experimental means. The net result is that the signal interaction would be impossibly large if the sense wires ran continuously through all 128 core planes and the basic geometry were used. It appears possible, however, to arrange the geometry such that the interaction can be reduced to a tolerable magnitude, at least if the sense wires are broken into four parts so that they thread only 32 planes each. Further investigation is necessary before any definite conclusions can be reached.

(S. R. Ray)

The memory read amplifier was analyzed using the Illiac program code number 1206. The purpose of this analysis is to determine if an additional circuit can be incorporated to tell if and when an incoming signal has arrived. Another purpose is to determine if the minimum signal-to-noise ratio can be reduced from the present seven (see drawing M-774) to three. This would allow for a minimum signal to gate of about 100 mv and a maximum signal to NOT gate of about 30 mv.

(A. B. Lindquist)

4. Input-Output and Auxiliary Storage

A four-stage ring counter has been designed for counting rates in the range 1 kc to 300 kc, using GF 45011 transistors. Modifications to permit the use of less expensive transistors in the final model are being studied.

(R. L. Cummins)

High density magnetic recording was studied. The principle of superposition was applied to determine graphically the interference in read-back voltage due to pulse crowding. The broadening of the read-back pulse due to poor read head resolution was calculated.

(C. N. Liu)

Study of the applications of thyristors is continuing. The triggering requirements are being investigated to find if useful counters can be designed

with an over-all saving in components.

(T. A. Murrell)

5. Test Equipment

An oscilloscope sweep calibrator was completed. It has a 5 mc crystal to drive the first stage with four outputs available of 5, 10, 20 and 40 mc each. These outputs will be used to calibrate the oscilloscopes.

(A. B. Lindquist)

6. Component Procurement and Testing

Data received from transistor manufacturers is insufficient to determine which of the presently advertised medium speed, high power transistors might be suitable for memory and driver work. It appears necessary to buy samples and test them with tests which are potentially destructive, e.g., apply currents to the transistors which are commensurate with collector dissipation ratings but exceed maximum collector current ratings. A list of potentially suitable transistors will be compiled.

(J. L. Muerle)

PART II

MATHEMATICAL METHODS

1. Einstein Field Equations (Supported in part by the National Science Foundation under Grant G-2794.)

The Einstein field equations for spherically symmetric static distribution of a relativistic gas at a constant entropy have been integrated. Curves have been computed which give the mass and radius of the distribution as functions of the central temperature. From these, one may determine a mass-radius relation. This coincides with the mass radius relation of a polytrope with $n = 3/2$ for values of these variables in the neighborhood of the mass and radius of the sum. However, the mass as a function of the radius has a maximum. Thus, this theory predicts that there is an upper bound to the mass of a distribution of matter which can be at a constant entropy. Further, there is a lower bound to the radius of the distribution below which the line element is singular. For some values of the mass there are two possible values of the radius.

In order to clarify various questions which arise in connection with the interpretation of the curves mentioned above, a study is being undertaken of small isentropic motions of a spherical distribution of matter in general relativity.

(H. Minn and A. H. Taub)

2. Monte Carlo Methods (Supported in part by the Office of Naval Research under Contract N6ori-07130.)

The SPINNAKER program for the body-centered cubic Ising lattice has been completely code-checked and put into operation. To date 13 runs have been made, each of 100 passes through the lattice. Four of these were on a 4 x 4 x 4 cell array, the remainder on an 8 x 8 x 8 cell array. Various temperature parameters, both above and below the Curie point, were used with no external magnetic field, and the results agreed well with those of Wakefield's series approximations (Proc. Camb. Phil. Soc. 47, 1951).

The program will handle 16 x 16 x 16 cells, and one or two runs on this lattice are proposed, purely as a check of the effect of the periodic boundary conditions. This will take six minutes for every pass through the lattice.

(D. Handscomb)

PART III

ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

Machine Use

During December, specifications were presented for 15 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1257. Numbers followed by T are for theses.

1257 Physics. Least Squares Fit to Co^{60} Data. Illiac will be used to find the 4th, 5th, 6th, 7th and 8th degree polynomials that are the least squares fit to the variation of γ-ray counting rate vs. temperature at four different angles with respect to the axes of a Tutton Salt in which the Co^{60} nuclei are imbedded.

1258 University of Michigan (Mental Health). Mental Health Research. It is desired to factor analyze the responses of three samples of 300 individuals to 140 personality variables. This requires finding the intercorrelations between these 140 variables for each of the three samples with Library Routine SSL 2.00, then finding an arbitrary vector basis for the space determined by these intercorrelation matrices with SSL 1.20, and, finally, performing a transformation on these arbitrary bases to "psychologically interesting" bases with 1.80.

1259 Computer. Rate of Flow in a Branching Process. Given $A_{mo} = 1(m \geq 0)$, $A_{on} = 0(n \geq 1)$, $t_m = \sum_{n \geq 1} A_{mn}$, $p + q = 1$, $p = \delta/r$, $0 < \delta < 1$, $A_{m+1,n+1} = (p\,A_{m,n+1} + q\,A_{mn})^r$, it is desired to investigate how t_m behaves as a function of m (for large m) when $r = 2$ and $r = 3$ and δ varies in $0 < \delta < 1$.

1260 Education. United Cerebral Palsy Language Study. A battery of tests for the differential diagnosis of language development of exceptional children is to be constructed. For the purposes of item selection and analysis, as well as for

securing information on test parameters, the digital computer will be used for calculating the inter-item, item-test, and inter-test correlations.

1261 Physiology. Effect of Diet on Sedimentation Rate of Human Red Blood Cells. Eight young men, during a five-month period in 1953, were fed a wide variety of diets. These experimental nutrient mixtures seemed to have caused fluctuations in the rate at which red blood cells sedimented in a standard laboratory test of the sedimentation rate. The fluctuations appeared to be greater than differences between individual subjects. The statistical problem is to find if these fluctuations of sedimentation rate are significantly correlated with the various dietary changes which these men experienced. The mathematical method for the analysis is the method of least squares.

1262 T Physical Education. Prediction of Treadmill Run for Boys 10-15. It is desired to predict the treadmill run of boys 10-15, using measures of O_2 intake and O_2 debt incurred under stress. There are 57 cases and 33 variables in the problem. Also, a standard score table for each of the 33 variables will be set up.

1263 T Chemistry. Studies of Nuclear Magnetic Resonance. A theoretical calculation of the proton-proton coupling constant in silane is being done. The first Illiac calculation is to extrapolate some atomic energy levels, known for other atoms, to obtain needed values for silicon. A floating-point program will be used for this. Later, there will be atomic integrals to evaluate, and probably other at present, unforeseeable, calculations. Other problems in this same general type will also be done later.

1264 Civil Engineering. Analysis of Dynamic Response of Highway Bridges. Sixteen highway bridges have been constructed as part of the AASHO Test Road in Ottawa, Illinois. The object of the research program is to analyze and interpret the data obtained in the dynamic tests being made on the test bridges of that road test project. A method of analysis of the behavior of highway bridges has been developed (Problem Specification No. 905 T). One of the objectives of the research program is an attempt to correlate the field test results with those

obtained by mathematical analyses. While a number of solutions will be obtained, using the above-mentioned routine as it is, it may become necessary in the future to modify this routine in order to accommodate certain physical features of the test set-up which have not been considered in the present form of the routine.

1265 Civil Engineering. Static Analysis of Test Road Bridges. Influence surfaces for deflections and moments due to static vertical loads will be obtained. The method of finite differences is used. (See U. of I. Eng. Exp. Sta. Bulletin No. 439). The bridge is represented by a rectangular gridwork of five longitudinal lines corresponding to the three beams and two lines midway between beams, and eleven transverse lines corresponding to the 12th points of the span. This results in a system of 55 simultaneous equations. The column vector of constants is made up by loads so chosen that the solution of the system of equations yields directly the desired influence surface. The constants entering the equations are computed from the input parameters. The equations are then generated, one at the time, under control of Illiac Library Routine L6 (Solution of Simultaneous Equations). When all the equations have been generated, L6 performs the solution, and the answers are printed out. The program is then ready to return for the computation of another influence surface for the same set of parameters.

1266 Aeronautical Engineering. Chemical Equilibria. The determination of the equilibrium composition of a system for a number of values of three parameters, α_K, K = 1, 2, 3, is to be carried out. To find the equilibrium composition it is necessary to solve the non-linear system

1) $$f_i(\bar{x}_j, \alpha_k) = 0$$

for the equilibrium values of the mole fractions, $\bar{x}_j$. Let

2) $$\sum_i [f_i(x_j, \alpha_k)]^2 = S \quad .$$

The solution of 1) will be obtained by minimizing S, using H-6.

1267 Eastern Illinois University (Botany). Analysis of Daily Radial Growth in Trees. Daily growth of trees varies, depending upon both the environmental conditions and the heredity of the tree. In this study the daily growth of six

trees in different environments and of different heredity has been measured throughout 1958. A number of daily environmental factors has also been measured. It is the purpose of this study to find out:

1. what variables will be the best predictors of growth;
2. in what way may growth vary with each significant factor (up to a third degree polynomial);
3. at what time of the season is each factor effective?

K-14 will be used to determine the best combinations through elimination of the non-significant variables. When the best set of independent variables has been found, then the curves of growth against each factor, while all other factors are held constant, will be found. Also, the data for separate periods in the season will be analyzed to find when each factor is most limiting to growth.

1268 Physics. Particle Orbits in Deflecting Magnet. Equations of motion of particles in a magnetic field are to be integrated by F1 with "time" as the integration parameter. The equations, in two dimensions, are:

$$r' = u$$

$$\Theta' = w$$

$$u' = rw^2 + rw(B \frac{q}{m})$$

$$w' = \frac{2wu}{r} - \frac{u}{r}(B \frac{q}{m})$$

with $(B \frac{q}{m})$ given as a function of (r, Θ) from measurements on the actual magnet. Output is in terms of the position and angle of deviation of the beam in the field-free region.

1269 Electrical Engineering. Electromagnetic Problems in Non-separable Coordinate Systems. The research is concerned with boundary-value problems in electromagnetic theory using non-separable coordinate systems. The motive for the research is the calculation of the patterns of antennas which are mounted on bodies of various shapes such as aircraft, missiles, buildings, etc. The first phase will be concerned with

the choice of suitable coordinate systems. It is proposed to investigate both cyclindrical and rotational coordinate systems based on a certain conformal transformation. This transformation, which is basically a generalized Jowkowsky Transformation, has properties particularly suited to the proposed applications. It is proposed to use the Illiac to determine the coefficients c_n required to produce a given coordinate surface by numerical methods. An iterative method is being devised for finding the c_n when x and y are specified by a table of numbers. Having found the coordinate system, the next step is to solve the following integral equation.

$$\int_{\text{Surface}} (\underline{E}_1 \times \underline{H}_2 - \underline{E}_2 \times \underline{H}_1) \cdot \underline{n}\, d\, S = \int_{\text{vol.}} (\underline{E}_1 \cdot \underline{J}_2 - \underline{E}_2 \cdot \underline{J}_1)\, dv$$

where $\underline{E}_1$, $\underline{H}_1$ is a Maxwellian field due to currents J_1 and $\underline{E}_2$, $\underline{H}_2$ is a Maxwellian field due to currents J_2 of the same frequency. In a typical problem the equation reduces to the following simple equation

$$\int_0^{2\pi} H_v\, H_n^{(2)}\,(k\,\rho)\,\cos n\,\phi\; h\; dv = \underline{k}\, H_n^{(2)}\,(k\,\rho_o)\,\cos n\,\phi_o$$

where $H_v = \sum a_m\, e^{imv}$

$\rho = \sqrt{x^2 + y^2}$

$\phi = \tan^{-1} y/x$

h = metric coefficient .

It is proposed to determine the a_m by numerical integration and solving the resulting set of linear simultaneous equations. Having found the a_m, a second application of the above integral equation will determine the required field components.

1270 Civil Engineering. Dynamic Analysis of Arches. The research problem is concerned with the computation of dynamic response to a triangular blast pulse moving across the arch. The modal analysis approach is used. The data fed in are the normal modes and the corresponding natural frequencies. The model has 18 degrees of freedom, hence, 18 modes. The displacements of any are expanded as a

series in terms of normal modes and substituted into the basic second order governing differential equations. This enables a calculation of the modal partitipation factors which are the constants of the series to be made. The program computes the participation at every time interval in a sort of marching-type of solution, superposes the modes to compute the true histories of displacement, thrusts and moments. The program is general enough to be used for any radius or thickness of arch.

1271 Student Counseling Service, Chicago, Illinois. Freshmen Guidance Test Analysis. Analysis of the test is for two purposes:

1) to determine whether scores on various personality, aptitude, and achievement tests will differentiate between those students who withdraw voluntarily during their first semester in college, and those who remain for the entire semester and then are dropped for poor scholarship;

2) to determine the relationship between scores on an academic interest inventory which has been used in the Student Counseling Service for many years and a newer one which is to replace it in a few months. The relationships are needed to assist counselors in making the transition from the scores of the old inventory to those of the new one.

Table I shows the distribution of machine time for the month of December.

TABLE I

	Hrs:Min	
Regular Maintenance	19:44	
Unscheduled Maintenance	15:32	
Drum Engineering	31:57	
Leapfrog	32:14	
R.A.R.	4:56	
Library Development	:23	
Wasted	:00	
		104:46

Use by Departments

Computer	47:15	
Physics	24:35	
Control Systems Laboratory	55:14	
Structural Research	75:25	
Structural Research (AF 464)	30:03	
Civil Engineering (A.A.S.H.O. Road Test)	:28	
Psychology	7:45	
Psychology (AF-49-638-371)	:26	
Education	1:30	
Electrical Engineering	5:12	
Elect. Eng. (AF 6079)	2:23	
Sociology	7:10	
Chemistry	55:22	
Agriculture	21:43	
Inst. of Com. Res.	:08	
Inst. of Com. Res. (9067C)	5:39	
College of Medicine	4:00	
Bureau of Educational Research	3:43	
Theor. and Appl. Mechanics (ORD 593 IC)	2:08	
Economics	4:27	
Mechanical Engineering	4:31	
Mech. Eng. (ORD 1980)	:27	
Min. and Met. Eng. (AF 3789)	:02	
Student Counseling Service	1:27	
State Department of Public Welfare (1715)	3:08	
State Water Survey	1:58	
State Water Survey (SC 75055)	1:51	
Michael Reese Hospital, Chicago, Illinois	:33	
Testing Service, Princeton, New Jersey	:36	
University of Michigan (Mental Health)	1:51	
Classes	26:34	
Miscellaneous	10:10	
		407:44
		512:30

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7 a.m. and 10 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 10 a.m. together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogenous group of engineering, maintenance, and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared, using the period between 10 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:30-6:30 period (when the machine is checked) if no errors are found, the time is given to the "running" column. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for December.

TABLE III

Drum failures	9
Williams Memory	13
Reader	1
Punch	1
Input-output	2
Power Supply	1
Total	27

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	SCHEDULED ENGINEERING	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
12/1/58	19:29	:05	1	(1) Drum failure	4:26	:00	2:08	0
12/2/58	20:59	:00	0		3:01	:00	1:00	0
12/3/58	18:55	:02	2	(1) Drum failure (2) Williams Memory error	5:03	:00	1:42	0
12/4/58	19:49	:00	0		4:11	:00	1:28	0
12/5/58	20:14	:00	0		3:46	:00	:40	0
12/8/58	18:53	:02	3	(1) Drum failure (2) Williams Memory error (3) Williams Memory error	5:05	:00	1:06	0
12/9/58	18:59	:44	2	(1) Reader "D" error (2) Punch 3 error	4:17	:00	:52	0
12/10/58	21:04	:01	1	(1) Drum failure	2:55	:00	:40	0
12/11/58	19:41	1:17	2	(1) Input switch (2) Drum failure	3:02	:00	:50	0
12/12/58	21:01	:55	2	(1) Drum failure (2) Memory failure	2:04	:00	:41	0
12/15/58	21:22	:01	1	(1) Drum failure	2:37	:00	:40	0
12/16/58	21:32	:01	1	(1) Input failure	2:27	:00	:41	0
12/17/58	21:17	:00	0		2:43	:00	:40	0
12/18/58	21:13	:00	0		2:47	:00	:43	0
12/19/58	15:54	5:06	2	(1) 300 v. power supply failure (2) Williams Memory failure	3:00	:00	1:13	0
12/22/58	20:57	:04	2	(1) Williams Memory (2) Williams Memory	2:59	:00	:40	0
12/23/58	21:30	:30	3	(1) Williams Memory error (2) Williams Memory error (3) Drum failure	2:00	:00	:51	0

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	SCHEDULED ENGINEERING	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
12/24/58	4:00	:00	0	Computer shut off at 12 noon	:00	:00	:00	0
12/26/58	21:39	:36	2	(1) Williams Memory error (2) Williams Memory error	1:45	:00	:34	0
12/29/58	20:39	:21	1	(1) Williams Memory error	3:00	:00	:41	0
12/30/58	20:56	:06	2	(1) Williams Memory error (2) Drum failure	2:58	:00	:40	0
12/31/59	18:00	:00	0	Computer shut off at 4 a.m.	2:00	:00	:22	0
TOTALS	428:03	9:51	27		66:06	:00	18:52	0

Reports and Seminars

Seminars

"Iterative Methods of Solving Linear Algebraic Equations II", by G. H. Golub, December 1

"An 8192 Word Core Store", by S. R. Ray, December 8

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